NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. II. Dec. 1887. No. 2.

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ASHLAND BASIN NO. 4 AND THE MIXING AND HANDLING OF CONCRETE.

By Wilbur F. Learned, C. E., of Watertown, Mass.

Read at Manchester, N. H., June 16, 1787.

Water was introduced into the city of Boston on the 25th day of October, 1848. The source of supply was Lake Cochituate, which is situated for the most part in the town of Natick, about 21 miles from the State House. Except, at the southerly end of the Lake the shores are well defined by hills, which in connection with the diversified scenery renders it one of the most beautiful in the State, and its water even at the present day is considered excellent.

The safe yield of the water shed was taken at 10,000,000 gallons daily, and in calculating for the future wants of the city the conclusion was adopted that 7,125,000 gallons per day would be an ample supply for the public, domestic and manufacturing uses of the inhabitants when their number should amount to 250,000. This calculation was based on the supposition that a supply of 28½ gallons per capita would be sufficient. In less than 4 years from the date of its introduction the consumption of water was over 49 gallons daily to every inhabitant in a population of 140,000. During the year 1852 the daily consumption was 58 gallons for each inhabitant of the city, being 1,000,000 gallons per day more than the quantity supposed to be required for a population of 250,000. A consumption of 60 gallons per day was reached in the year 1854, 63½ gallons per capita in the year 1855 and in the year 1856 the consumption was 70 gallons per day for each inhabitant of the city according to the method used at that time for computing the amount used. The consumption of water had become so much in excess of the original calculation, that in order to save a portion of the water that was yearly flowing over the outlet dam, the Lake was raised 2 feet. Three years later or during the year 1862. Dudley Pond, situated about ¼ mile from the north end of the Lake was connected with it, making the total area of water surface when at high water mark 925 acres.

In less than 25 years the demands of the city on the water supply were greater than the Lake could meet, especially in dry years, so that steps

were taken to construct additional works with Sudbury River as the source of supply.

The new system, as originally designed by Mr. J. P. Davis and partly executed by Mr. A. Ftely, consists of 7 storage basins and 2 ponds. Farm Pond in Framingham and Whitehall Pond in Hopkinton, with a conduit extending from Farm Pond to Chestnut Hill Reservoir, a distance of 14 miles.

Four of the Basins have been built, and it is with reference to Basin No. 4 that we invite your attention to-day. Basin No. 4 is situated in Ashland on Cold Spring Brook, about a mile from its confluence with Sudbury River.

Its drainage area is 6.06 square miles.

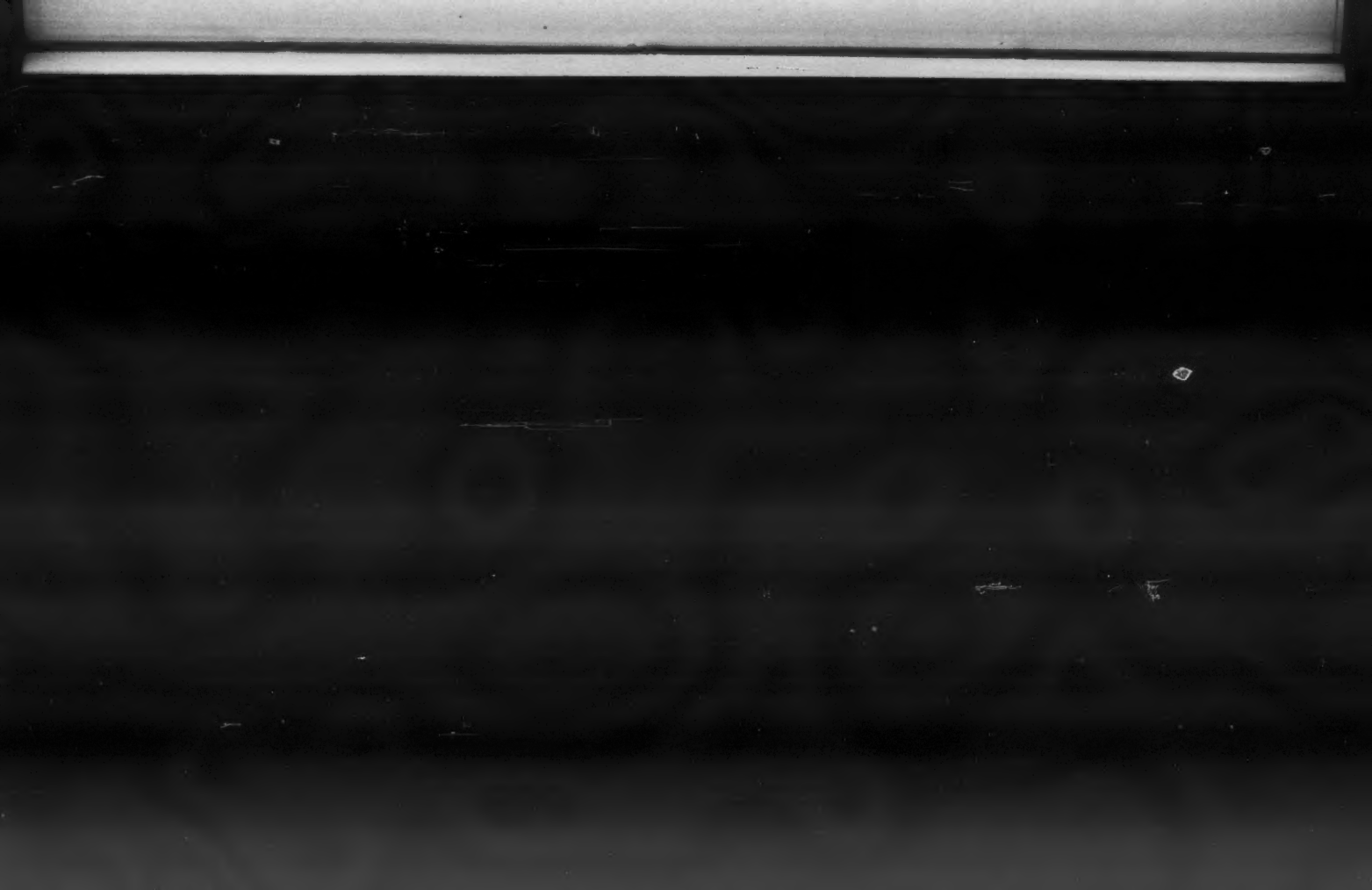
That portion of Cold Spring Brook Valley which forms Basin No. 4 was specially adapted for a reservoir; the hills on either side are from 75 to 100 feet in height, and for the most part have steep slopes which in remote ages undoubtedly formed the boundaries of an immense glacier, as the drift and boulders in this neighborhood indicate. The drift at the site of the dam varies from 12 to 30 feet in depth, and is underlaid by granite.

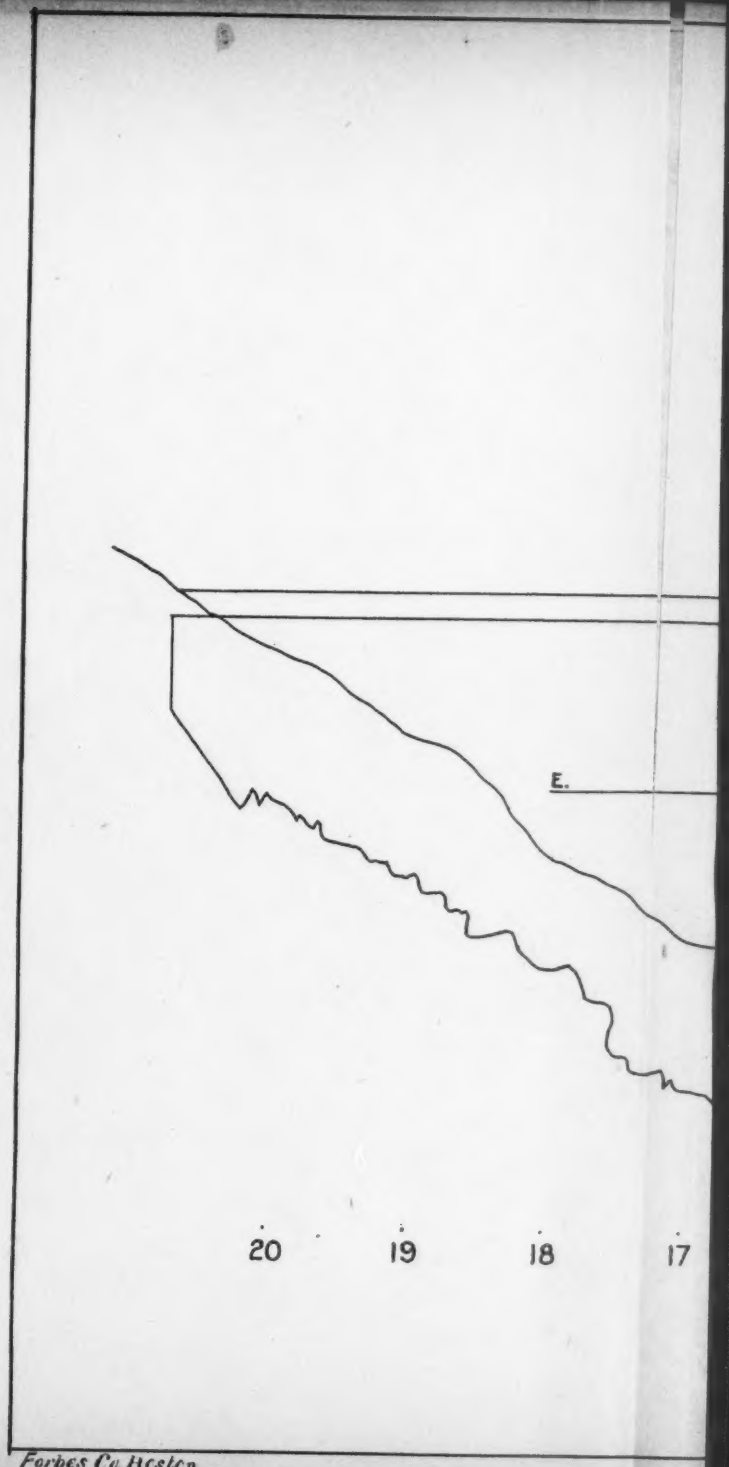
The dam was built where the configuration of the hills would admit of the greatest economy with due regard to a maximum capacity of Basin.

Work was commenced in the autumn of 1881, under the immediate supervision of Mr. C. S. Gowen.

After the first year all the work was done by city laborers who were paid at the rate of $1.80 per day, and from the beginning to the end all teams employed were paid for at the rate of $5 for single and $4.50 for double teams. All the permeable soil at the site of the dam was removed and a trench 16 feet in width was excavated to bed rock for the concrete core. After the core had been built to the level of the ground, and the foundation of the gate chamber finished to the same level, the construction of the core and gate chamber and also the building of the dam were carried on together until the completion of the work. The core in the trench through the meadow, excepting at the gate chamber foundation, has a uniform thickness of 8 feet except at irregular intervals of 150 feet or more buttresses 3 feet wide and 1 foot thick break the continuity on the water side. Above the grade of the meadow the width decreases in successive gradations for each vertical section of 8 feet until it is 3 feet in width on top. Its maximum height is 80 feet above bed rock. The inside face of the core is covered with a half inch coating of Portland cement mortar, subsequently covered with a thick wash of clear Portland cement. During hot weather, and in fact more or less during the application of the plastering, fine hair cracks would appear on the surface which was subsequently re-covered until the plastering was entirely free from any defect that impair its imperviability.

At the commencement of the work the materials used for building the dam were found in an adjoining hill, and were specially suited for the purpose, consisting of clay, fine sand and gravel, which were transported by teams. After this borrow pit became exhausted the materials, with the exception of the clay, were transported from a more distant part of the Basin in cars by a steam R. R. which was laid on the dam, a single track being placed on each side of the concrete wall.





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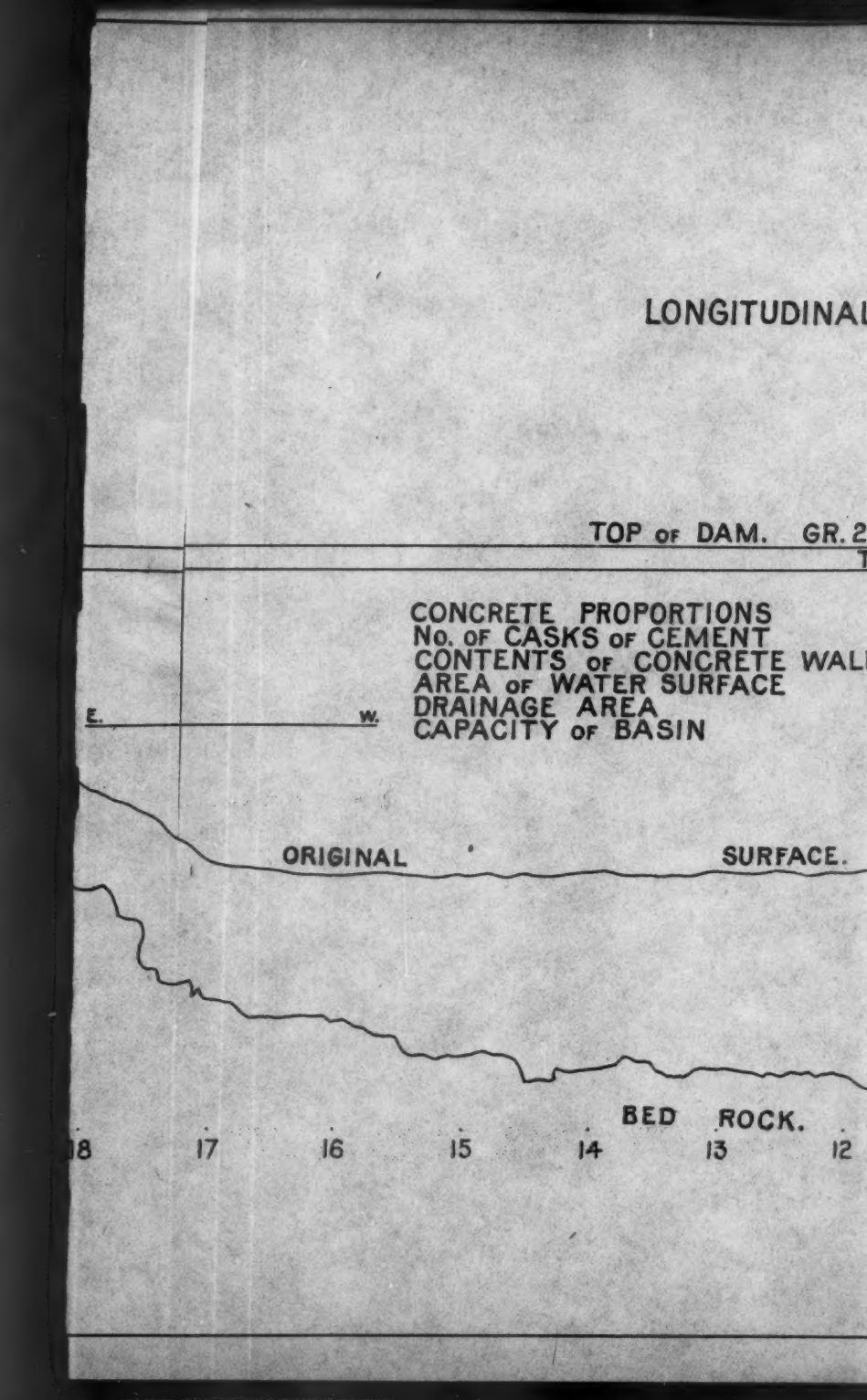

LONGITUDINAL
TOP OF DAM. GR. 2
CONCRETE PROPORTIONS
No. OF CASKS OF CEMENT
CONTENTS OF CONCRETE WALL
AREA OF WATER SURFACE
DRAINAGE AREA
CAPACITY OF BASIN
E.
W.
ORIGINAL
SURFACE.
BED ROCK.
18
17
16
15
14
13
12

/

UDINAL SECTION OF DAM.

HOR. SCALE 5.
VERT. " 1.

GR. 221.

TOP OF CONCRETE. GR. 217.5

1-2-5
28,000
E WALL 20,900 CU. YDS.
E 162 ACRES
6.06 SQ. MILES.
1,404,000,000. GALS.

FACE.

GR. 138.

K.

12 11 10 9 8 7 6

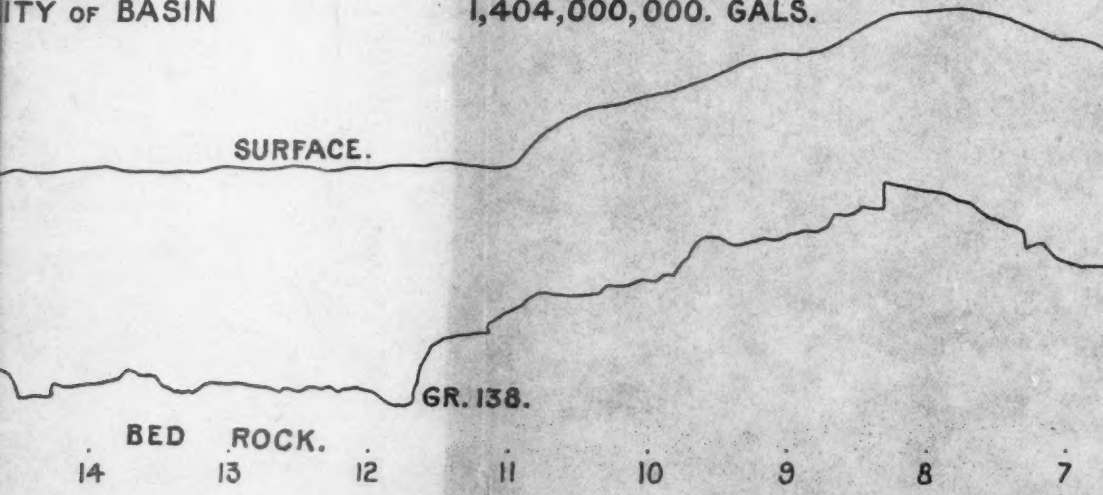
LONGITUDINAL SECTION OF DAM.

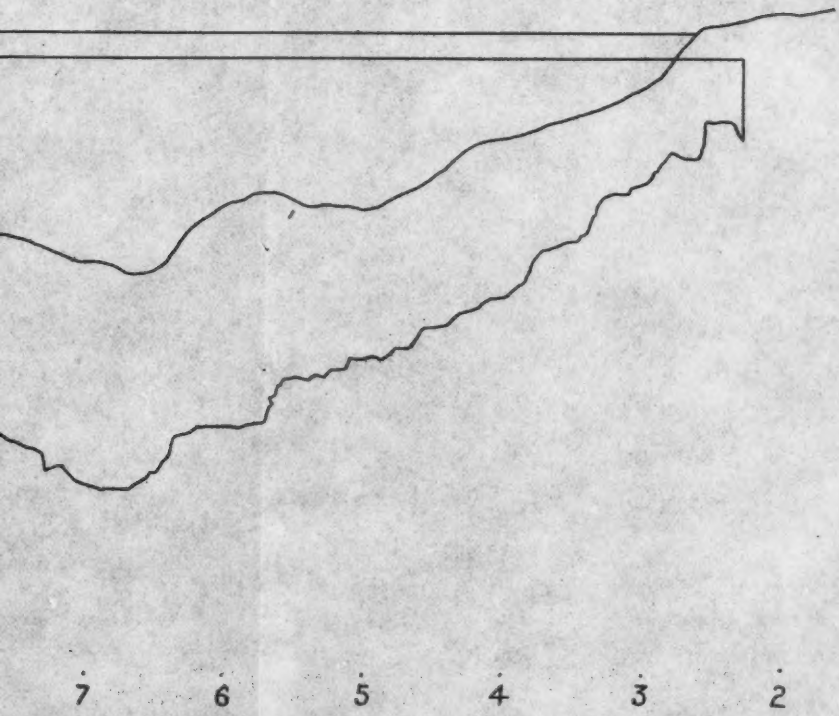
HOR. SCALE 5.
VERT. " 1.

TOP OF DAM. GR. 221.

TOP OF CONCRETE. GR. 217.5

ETE PROPORTIONS	1-2-5
CASKS OF CEMENT	28,000
NTS OF CONCRETE WALL	20,900 CU. YDS.
OF WATER SURFACE	162 ACRES
AGE AREA	6.06 SQ. MILES.
ITY OF BASIN	1,404,000,000. GALS.

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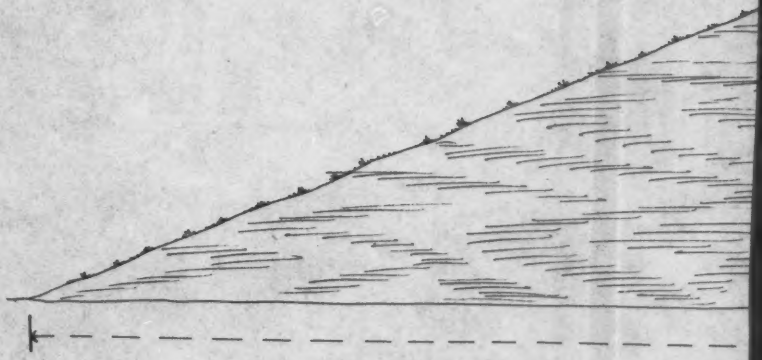
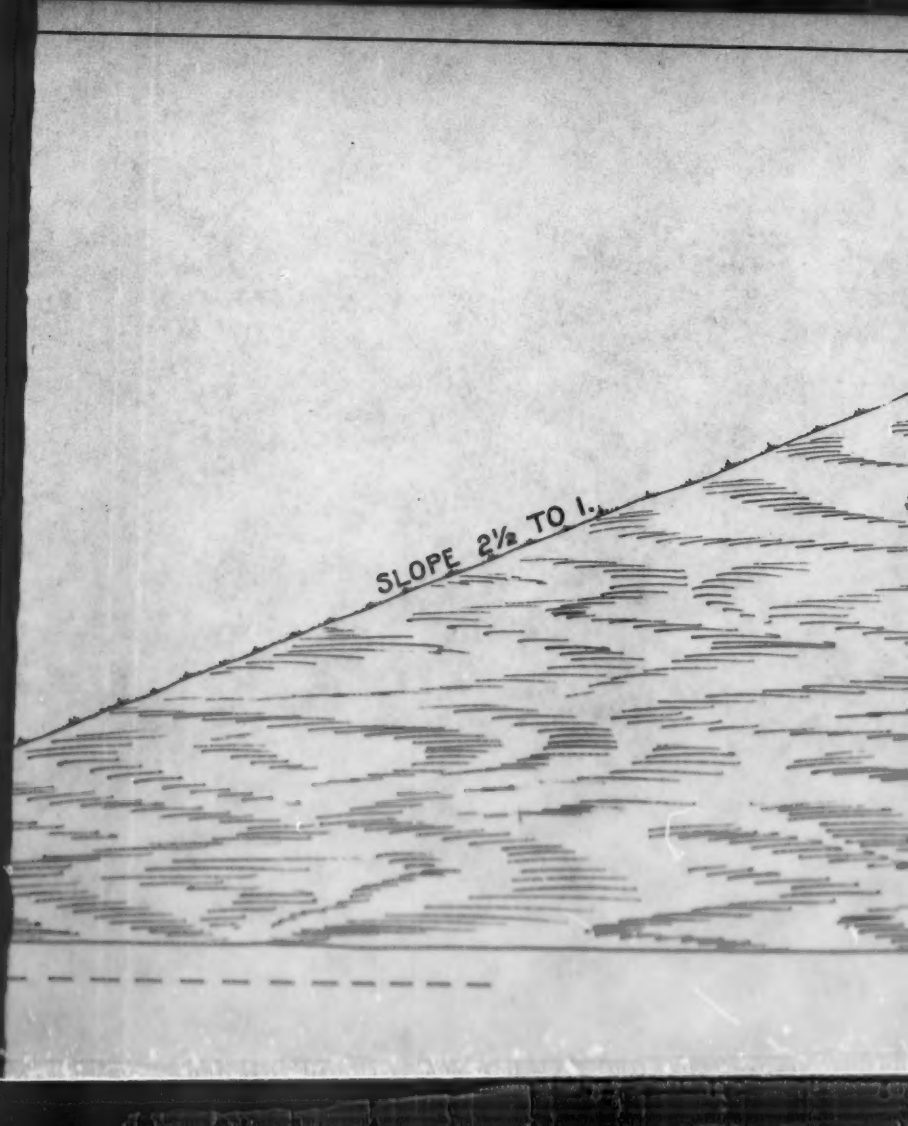
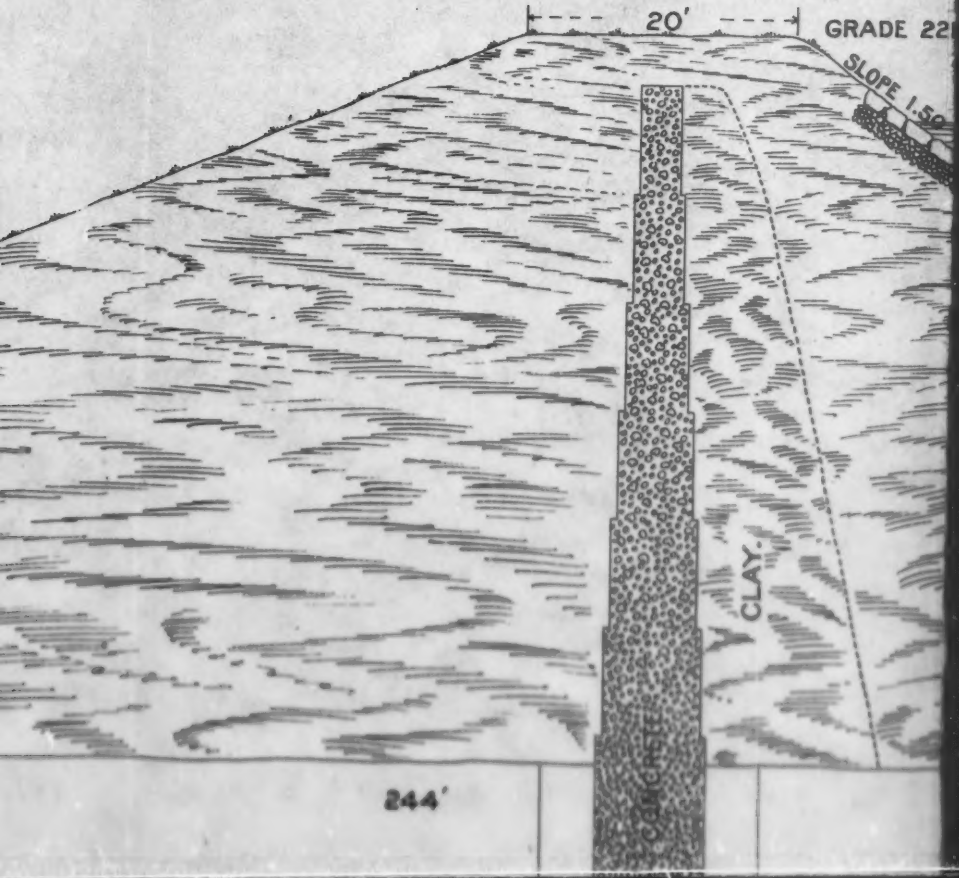


Forbes Co. Boston


SLOPE 2½ TO 1.

GENERAL SECTION OF DAM.



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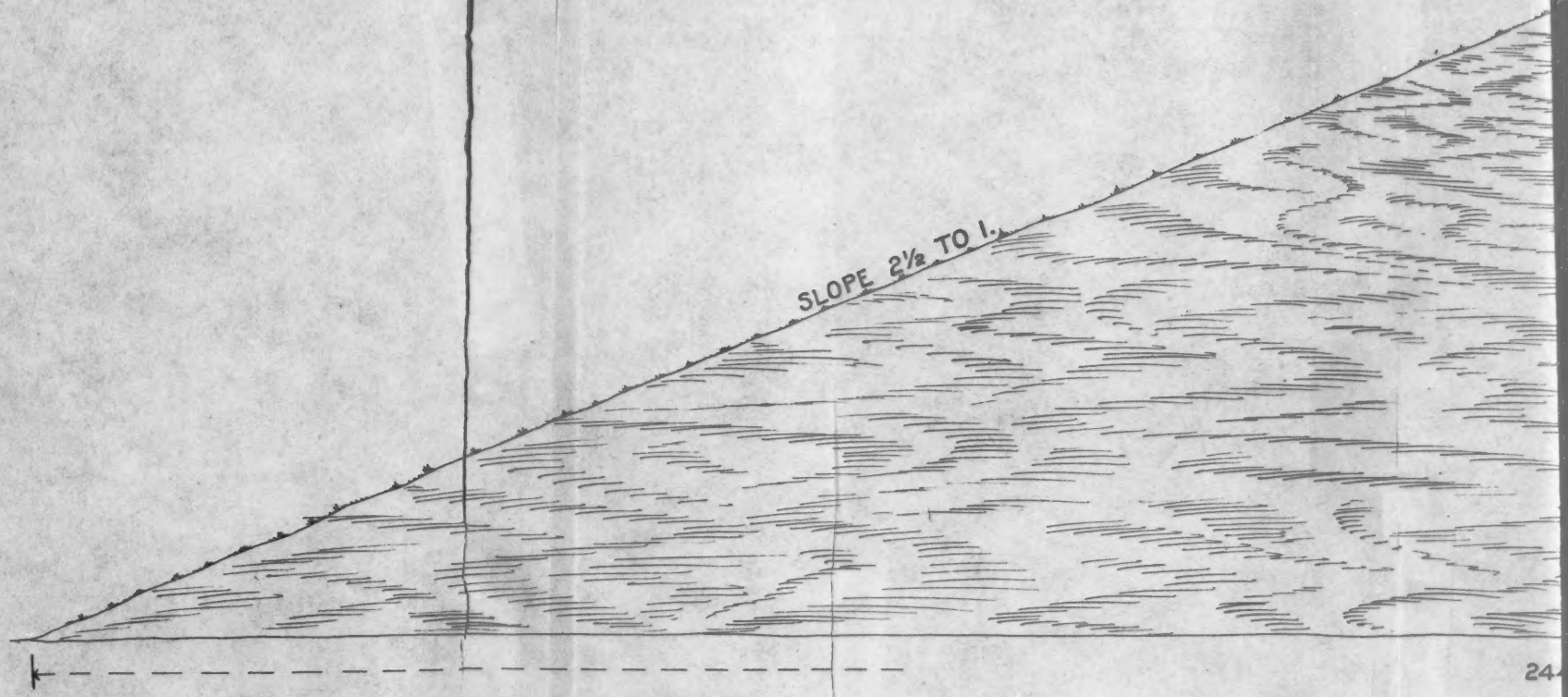

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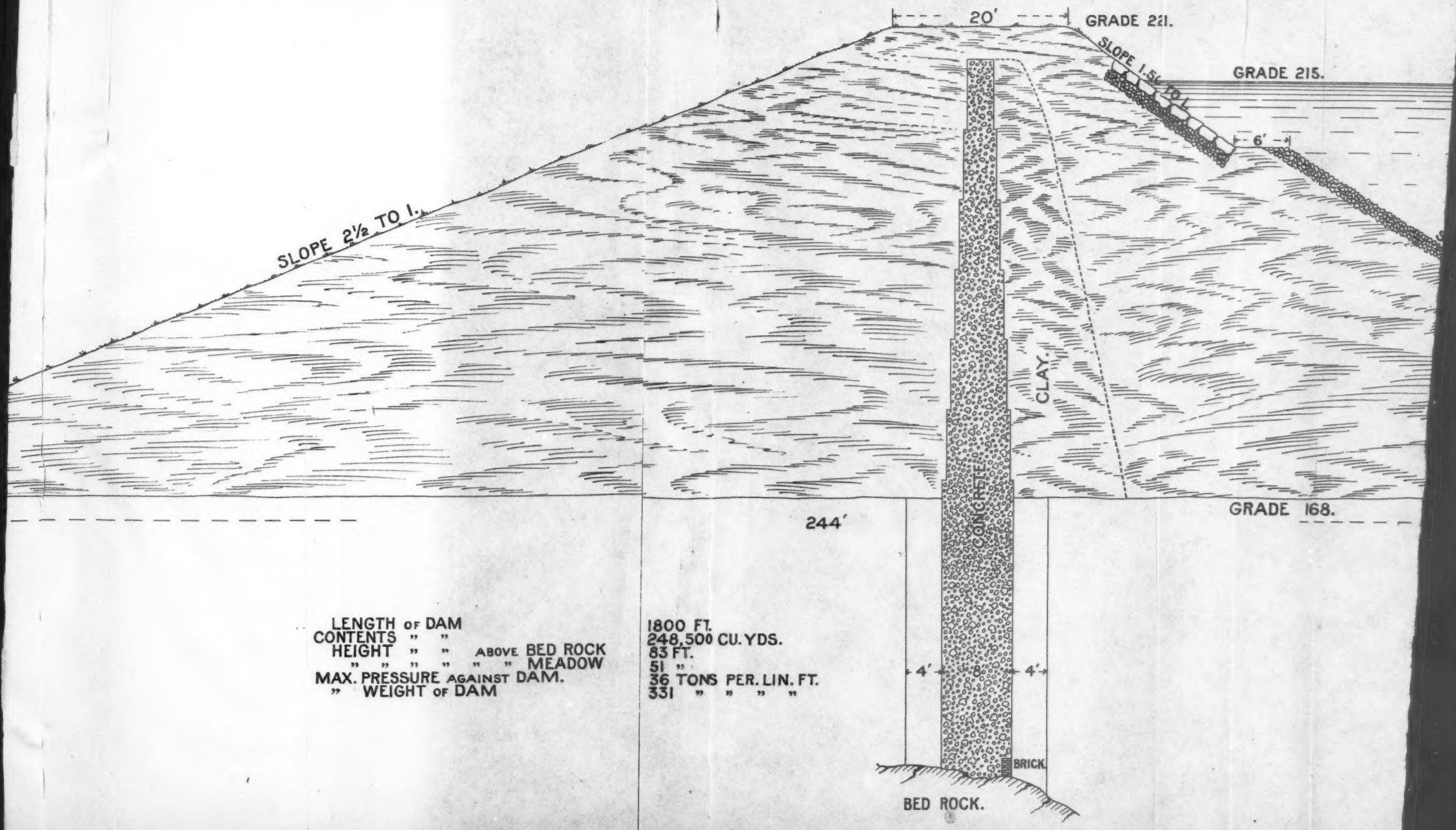
LENGTH OF DAM	1800 FT.
CONTENTS " "	248,500 CU. YDS.
HEIGHT " " ABOVE BED ROCK	83 FT.
" " " " " " MEADOW	51 "
MAX. PRESSURE AGAINST DAM.	36 TONS PER. LIN. FT.
" WEIGHT OF DAM	331 " " " "

Forbes Co. Boston

GENERAL SECTION OF DAM.



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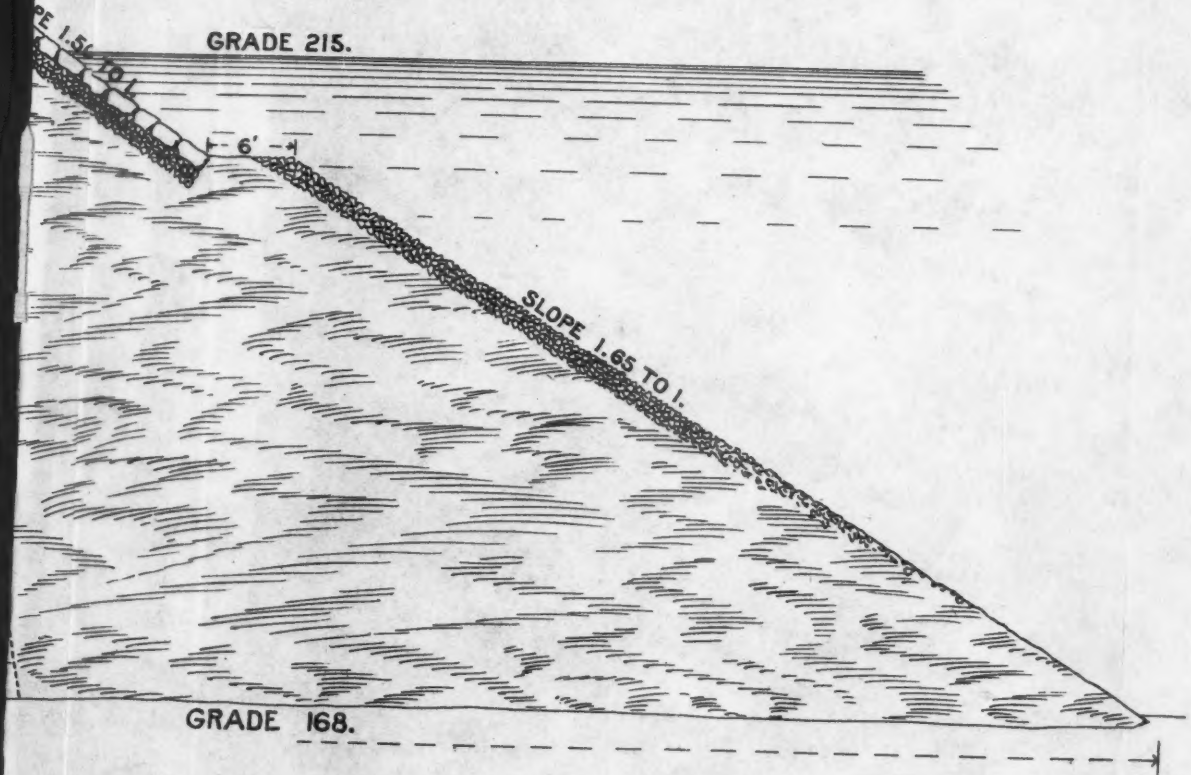

The spaces in the trench on both sides of the concrete core were back filled with clay on the water side, and with fine sand on the outer side.

Above the level of the ground the materials were placed in 8 inch layers, care being taken to have the outer portions of the dam considerably higher than the inner portions, all of which were thoroughly watered and rolled with heavy grooved rollers.

Clay was placed against the core on the water side for an average width of 10 feet, then fine sand adjoining the clay merging into fine gravel, and lastly coarse gravel outside. On the down stream side fine sand and gravel were used with sand against the core and extending toward the slope where gravel was used.

The railroad from the gravel bank to the dam was about ½ mile in length, of standard guage, and connected with the Hopkinton R. R. which in turn connected with the Boston & Albany R. R. so that facilities were had for delivering all the freight and materials not found on the ground in close proximity to the work, and for the transportation of loam to Back Bay Park in Boston.

The excavation of the gravel and its transportation to the dam, and also the excavation and transporation of loam, was paid for by an agreement with Munson & Co., who furnished all the necessary plant excepting the track extending from the Basin to the Hopkinton R. R. The plant consisting of 5 locomotives, 100 dump cars, 2 steam shovels and 210 tons of track iron.

The rate paid for the gravel delivered on the dam was 26 cents per cubic yard, car measurement; the dumping, spreading and rolling of the gravel as well as the moving of the track, on the dam was done by city labor which increased the cost of gravel in place to 60 cents per cubic yard.

The excavation at the gravel bank was done by a steam shovel whose bucket was of 2 cubic yards capacity; the largest amount shovelled in any one day was was 1600 cubic yards, the average was 800 cubic yards.

The largest amount delivered on the dam during any month was 26,000 cubic yards, car measurement.

The stone used in the concrete and on the lower slope of the dam was obtained in the Basin and hauled in cars to a stone crusher, which was located side of the track at one end of the dam. The stone crusher was of the Blake pattern with an opening of 9 in. x 15 in.

The largest amount of stone crushed in any one day was 116 cubic yards, measured in place, the average was 80 cubic yards. The cost of crushing stone was 89 cents per cubic yard; the cost of collecting and delivering was $1 per cubic yard.

The water used on the dam was supplied by a Worthington Pump through a 2 in. diameter pipe which extended along the foot of the slope to both ends of the dam, thence by branch lines connecting with a line of pipe laid on the concrete core.

The system of pipes was connected with an elevated tank situated at one end of the dam. The pipe on the concrete core was fitted with 2 in. x 1 in. T's 100 feet apart for attaching hose, and streams of water were constantly applied during the construction.

The dam is about 1800 feet in length, measured on top, it is 51 feet in height above the meadow and 83 feet in height above the bed rock at its

deepest point. The width on top is 20 feet and 244 feet in width at the level of the lower part of the meadow.

The outside slope has an inclination of 2½ feet horizontally to 1 foot vertically, and is faced with loam to the depth of 12 inches at right angles with the slope. The inside slope of the dam above the berme is 1½ to 1 and is covered with granite paving 15 inches in depth laid on broken stone 12 inches in depth. The lower slope has an inclination of 1.65 feet to 1 and is riprapped to the depth of 18 inches with stone broken to the largest size that could pass through the crusher and would average such size as would pass through a six inch ring.

The dam contains 248,000 cubic yards of material. About two-thirds this amount was delivered on the dam in cars and was paid for by car measurement. A measurement on the dam, after being watered and rolled, showed a shrinkage of 21.3 per cent. from car measurement.

The gate chamber is located on the site of the brook where it crossed the line of the dam. Its foundation is built on bed rock, and consists of rubble masonry and concrete 21 feet in depth below the grade of the lower inlet and outlet pipes.

The gate chamber proper is divided into one effluent and two influent chambers which are built side by side and are respectively 32½ feet and 57 feet in depth below the floor of the gate house. The effluent chamber is also 57 feet in depth and includes the width taken up by the other two chambers. Each influent chamber is provided with an iron and a wood valve. The iron valves are for controlling the discharge of the water and the wood valves for cases of emergency. Both iron valves are provided with 6 inch diameter drainage holes, which may be opened on the effluent side of the valve, when the wood valves are closed and the iron valves do not work.

Provision is also made for filling the deeper influent chamber independently of the iron pipes so that the head of the water on the wood valves when closed may be reduced and then raised without much effort. There are two inlet and 3 outlet pipes of 48 inch diameter, the inlet pipes are situated one 21 feet above the other in the same vertical plane, except just outside the gate chamber masonry where the lower pipe diverts to the left and the upper pipe to the right in order to enter their respective chambers.

A connection is also made between the effluent chamber and the Basin by a water way 5 feet below high water mark. The effluent pipes are laid parallel with each other at the grade at the lowest part of the Basin. The overflow and the waste way are situated at the easterly end of dam. The crest of the overflow is built 1 foot below high water mark and is 30 feet in length. The waste way corresponds in width with the length of the overflow and extends along the sides of the hill somewhat like the arc of a quadrant, from a plane 5 feet below the crest of the overflow to the level of the meadow below, a depth of 40 feet.

The length of the Basin measuring on a line at right angles with the dam is a little over a mile, the greatest width is about ¼ of a mile. The capacity of the Basin is 1,404,000,000 gallons and will furnish at all times about 4,000,000 gallons daily.

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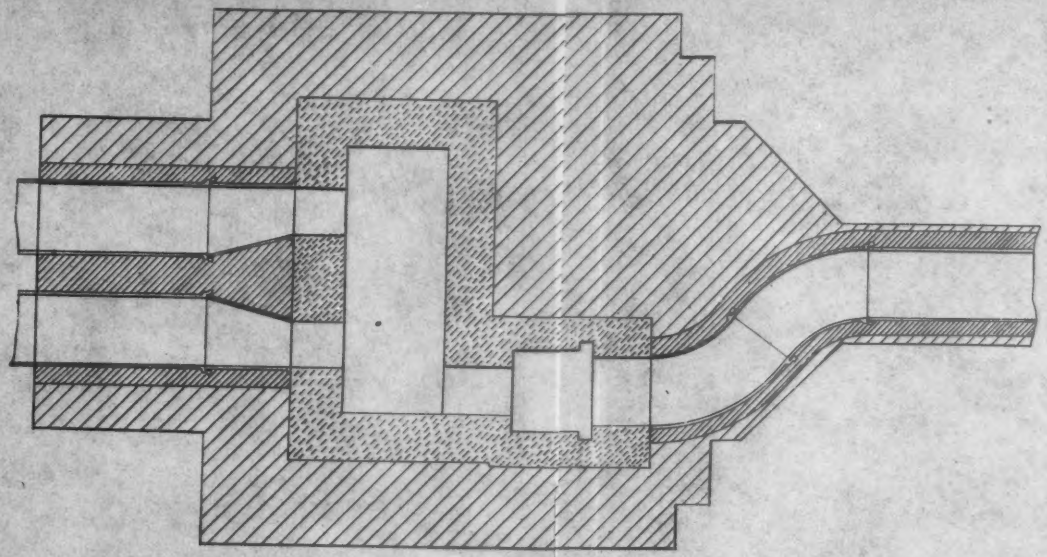

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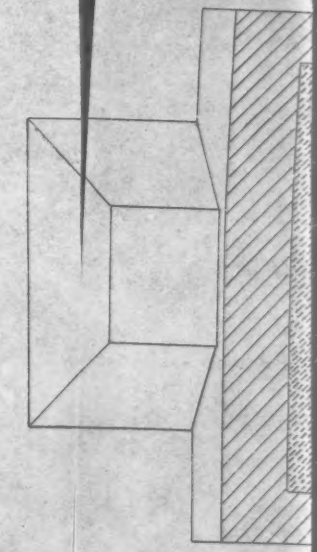

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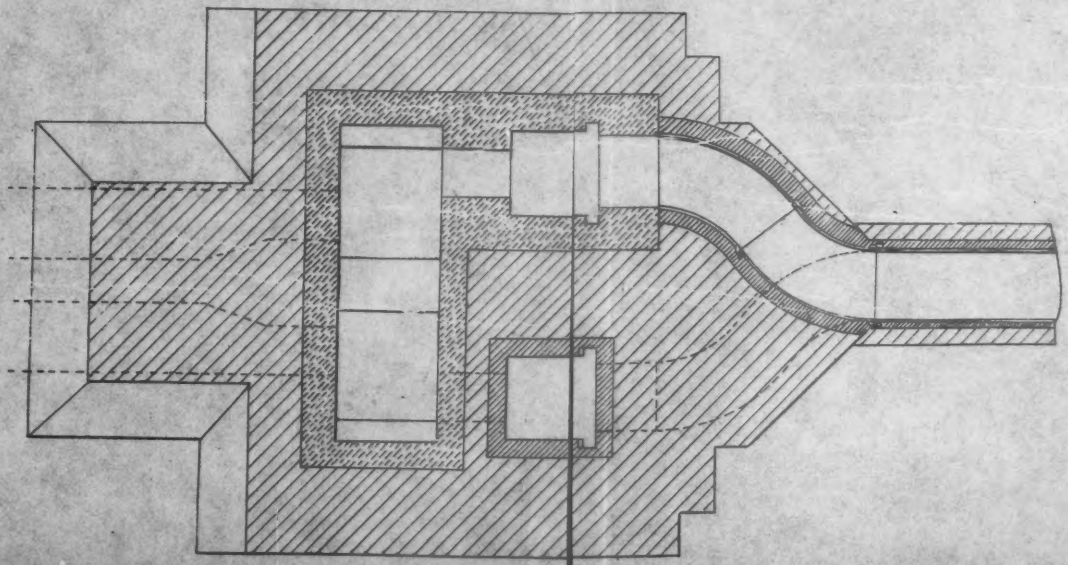

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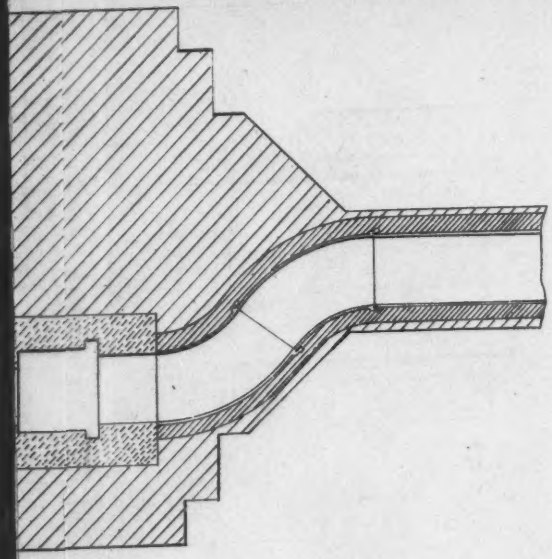
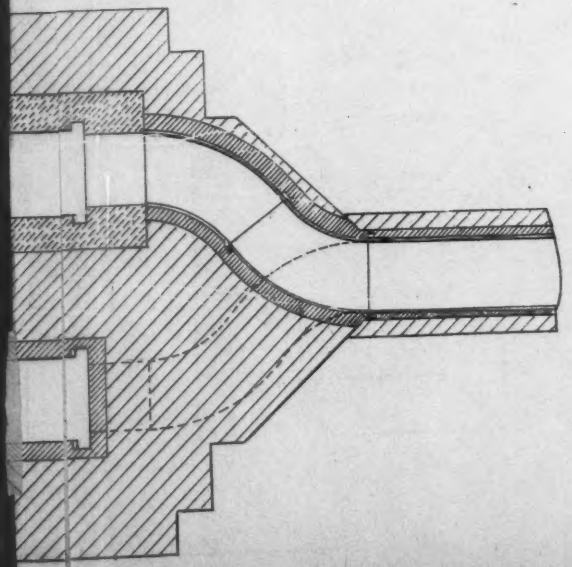
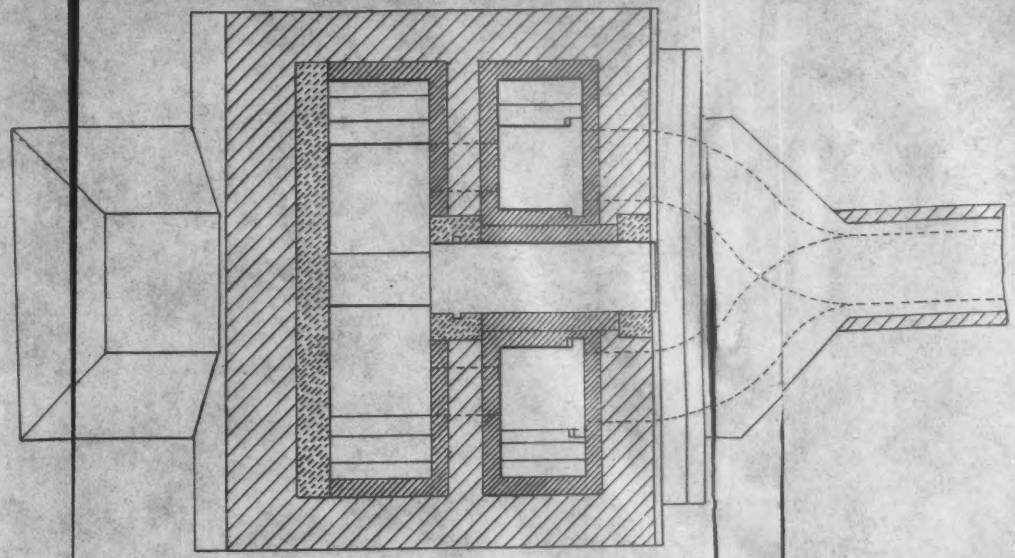
INE A.B.

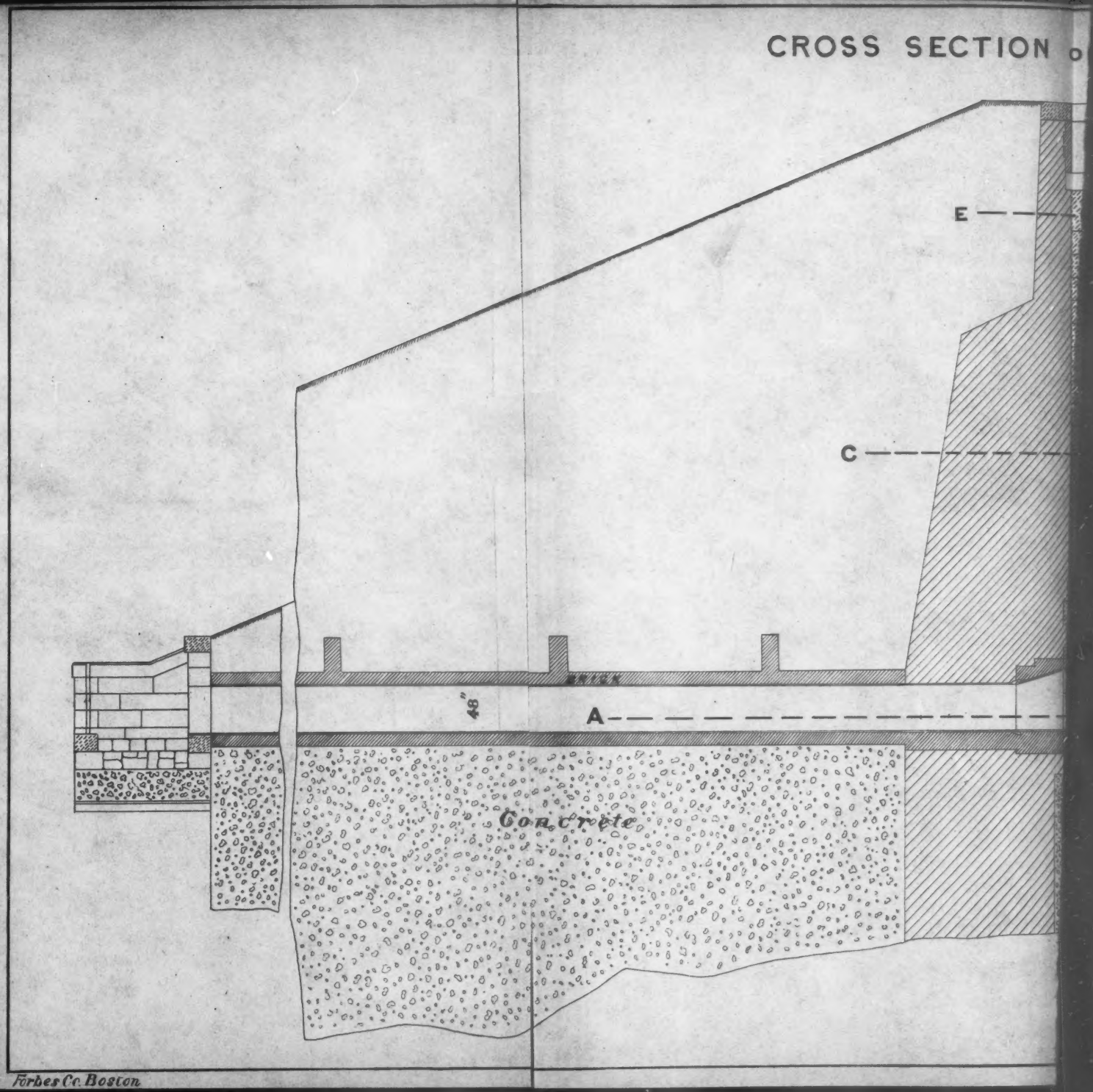


VE C.D.

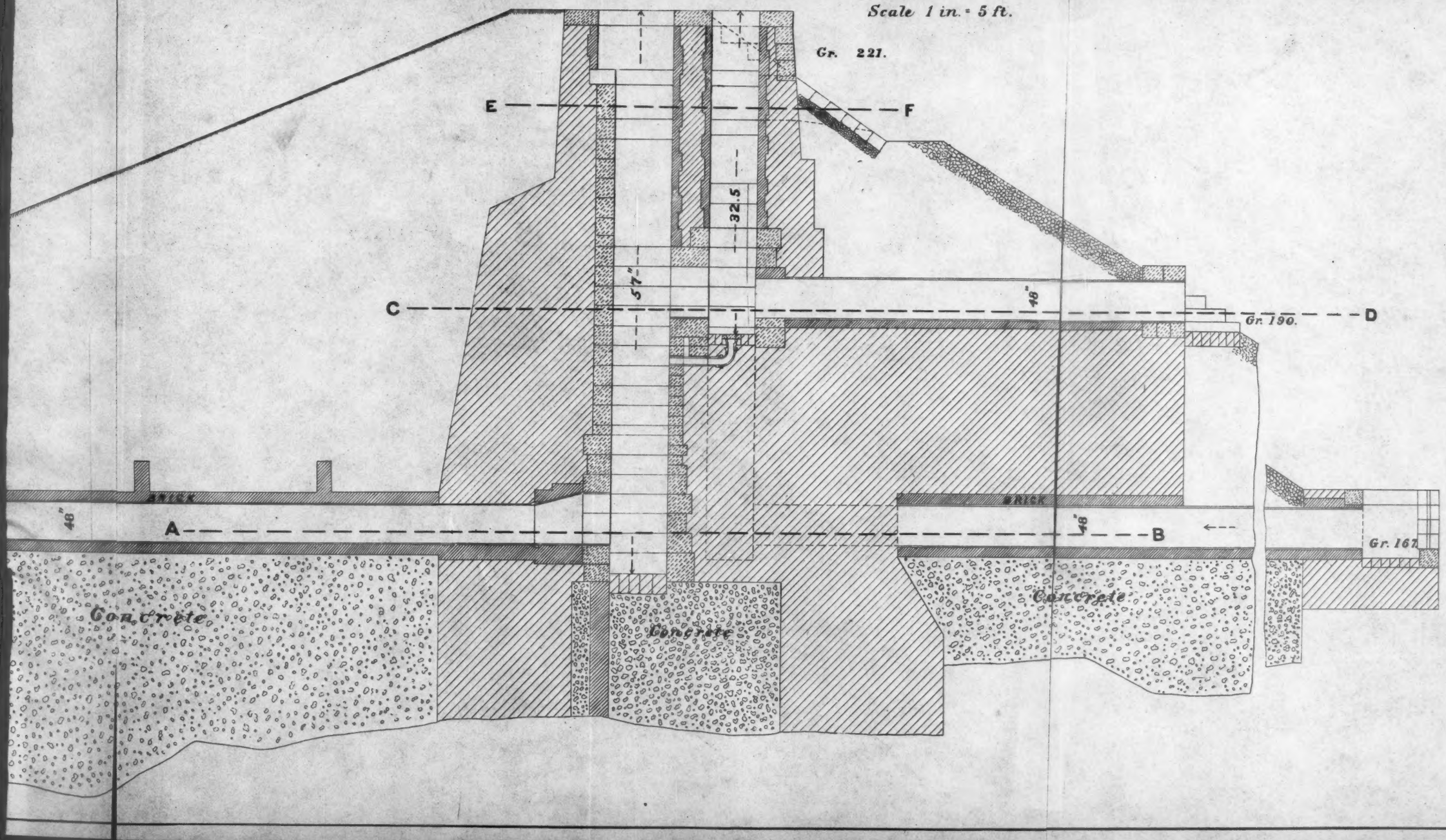


HOR. SEC. ON LINE E. E.




CROSS SECTION o
E
C
A
48"
Concrete
Forbes Co. Boston

CROSS SECTION OF DAM AND GATE HOUSE.



The removal of all the loam and muck in the Basin was first adopted by the Boston Water Board, who have since erected Basin Nos. 2 and 3 in a similar manner by eliminating all the shallow flowage.

MIXING AND HANDLING OF CONCRETE.

The particular brands of cement used on the work were Newark & Rosendale, and Newark Lime and Cement Company's Cement.

Each carload of cement as it arrived on the work was tested for tensile strength and for fineness, all casks being rejected that did not show a strength of 40 lbs. per square inch after the briquette had remained under water 24 hours or a degree of fineness of more than 10 per cent. as determined by a No. 50 sieve.

All the concrete was mixed in a machine of the pattern made by the Pioneer Iron Works of Brooklyn, N. Y. It consisted of a wrought iron V shape trough about 8 feet long on which a shaft was set with arms arranged in such position that they formed spiral lines from end to end of the trough.

An 8 horse-power engine ran the mixing machine and both were set on a strong platform.

The cement, sand and broken stone having been deposited on the platform convenient for using, the leader shovelled about 1½ shovels full of loose cement into the trough—an equivalent to one proportional part in the cask—at the same time a helper standing on the same side of the trough shovelled 2 shovels full of sand and two helpers on the other side of the machine shovelled 2½ shovels full of stone. The revolving shaft with a stream of water graduated to the speed of the engine and the requirements of the amount of concrete in hand stirred the materials into a thorough admixture and forced it in a continuous stream out of the trough into wheelbarrows ready for its disposal. The leader constantly watched the concrete as it passed out of the trough and would add a little more cement or sand when his experience dictated that it was not of the right consistency. Two men with shovels at the spout obstructed the flow of concrete so that a wheelbarrow load could be cut off in one operation. At ordinary speed the machine would keep from 8 to 12 men constantly wheeling away concrete, and at times when the length of wheeling was somewhat long, say from 75 to 100 feet the larger number of men were quite actively employed.

The quality of the concrete was regulated from time to time by measurering the amount of concrete wall built with a certain number of casks of cement, it having been determined by actual experiment that 1 cask of cement made 22 cubic feet of concrete when the ingredients were in the proportions of 1, 2 and 5. If it was ascertained that more concrete had been made than was allowed with a certain number of casks of cement, a little more cement was added than formerly and vice versa if the concrete fell short in amount. In any case the quality was seldom more than 1 or 2 feet over or under the correct amount.

It was found that the most convenient dimensions of wall to build in one section was 100 feet in length and 4 feet in height formed by frames built to the required height and width and connected by longitudinal bracing the sides consisting of cleated board were adjustable to any required

width, and were removed from contact with the wall before moving the forms into a new position.

The concrete was deposited in 6 inch layers and heavily rammed, a groove was formed in each layer on alternate sides by placing the concrete on both sides of a line of timbers of the required form, which were removed before a new layer was commenced.

The end of the section was formed in steps both vertically and horizontally, which, with the grooves of the layers formed a kind of lock for each succeeding section.

After completing a section of wall the sides of the forms were removed; a four fold block and tackle were carried ahead and made fast to an anchor. The rear block was attached to the engine platform and the rope fixed to the drum of the engine; when all were ready the throttle valve was opened, the drum winding the rope hauled the engine, mixer and forms,—all being connected,—along on a track laid for that purpose.

The old wall where the new section was to be built was then thoroughly swept and washed, the forms adjusted and the water pipe which laid on the wall was hung to the cross pieces of the forms.

The raised pipe was then connected at one end with the pipe on the section already built, and with a rubber hose made for the purpose was connected at the other end.

This method of moving the forms as well as the construction of the dam, was under the immediate supervision and direction of Mr. A. E. Martin, member of this Association.

The largest amount of concrete made in any one day was nearly 100 cubic yards or 120 casks of cement. The average amount was not far from 65 cubic yards or 80 casks.

The cubical contents of the wall was 20900 cubic yards comprising 25650 casks of cement. The average cost of the concrete wall was $4.32 per cubic yard.

DISCUSSION.

The Chairman. Mr. Learned's very interesting paper is now before you for discussion.

Mr. Richards. I would like to ask what size of stone was used in the concrete.

Mr. Learned. Such as would pass through a two inch screen, in the proportions of one, two and five. The size of the stone was not arbitrary; it may in some cases have exceeded that but generally it was that. We did not use any fine stone. The crushing of the stone and collecting it were not included in my statement of the cost of the concrete.

Mr. FitzGerald. Did it include the crushing.

Mr. Learned. I think not. It was simply the putting together.

Mr. FitzGerald. It included the sand?

Mr. Learned. The cost of crushing the stone was about 89 cents, and I know it cost $1.00 to collect; so that the collection and crushing of the stone cost about $1.90.

Mr. Fuller. How far did you have to go for the stone?

Mr. Learned. About half a mile. Such stone as you would use in a stone wall were broke up under a hammer and subsequently crushed by the machine.

Mr. FitzGerald. I think all such basins should be built with an arrangement for drawing the water from the surface and following the surface down as the water recedes, because almost always the quality of the water at the surface is better than a short way down. In this very basin we found that the water at the surface was good and a little way down it was very poor, the first year after it was built, and there was no way of drawing it from the surface and following it down; and we have found it very necessary to do that. A very cheap arrangement, and one which I think every gate house should have, is a set of planks, so you can keep taking out the planks as the water goes down, and thus you can draw from the surface all the time.

Mr. Sherman. Would you not recommend that for any reservoir, say of five, or ten, or twenty million capacity?

Mr. FitzGerald. That has been my experience.

Mr. Sherman. Would you prefer to draw from the surface always?

Mr. FitzGerald. Not always, perhaps, but once a week we take samples at different depths and find out how the water is. Generally the water is best at the surface, if the water is bad in the basin.

Mr. Ball. I have had in my experience one or two singular cases which bear upon this point, and it may be well to give them in detail. When our Worcester Water Works were first built, in 1864, no gate house was put in at the reservoir at all. The pipe was run into the bottom of the reservoir in the ordinary way, and the outlet gate was upon the outside of the building. The reservoir was filled first in November, 1864, and we began using from it the following spring. By the middle of June, the reservoir being entirely an artificial reservoir, the water had become so foul and so bad it couldn't be used. To come to the point, it was contaminated with sulphuretted hydrogen, and you could smell it with great distinctness when it was drawn from the pipes in the city. On going to the reservoir I found that the surface of the water was pure, tasteless, clear and perfectly good. I at once got a diver to go down and take off the wire which I had placed in front of the outlet pipe, the screen, hauled up the screen, and built a simple board box, I think it was about two feet square on the inside, and constructed a spout on the side of it. The outlet pipe was tapering, so I could fit the wood to the tapering end of the pipe ; I sunk down the box with this taper, then opened the gate on the lower side, and drew it in, so it made a tolerably tight joint. I had arranged the box so we could draw the water from the surface of the river. After I had it all arranged I then opened the gates, so that the water flowed from the surface, clear up close. In less than a week from the time they commenced drawing, the pipes had cleared themselves in the city, the water became so the people could use it, and remained so during the whole season. I think from that day to this the water never could have been used if it had been drawn from the bottom. There have been times, once ten or fifteen years after the reservoir was built, when an attempt has been made to draw from below the surfaee, but it could not be done and they had to resort again to drawing from the top.

When we constructed the gate house there we put in a continuous gate, two feet in width. There are narrow planks, I think eight inches in width, and our aim was never to take more than one plank off at a time, and we have drawn in that way summer and winter.

A short time after my Worcester experience I was called up to Keene to construct works there. I built a gate house there with a continuous gate. Those works ran with success for some years, without any trouble except a short time in the winter. For some time from about the middle of January to the first of March they were troubled with bad water, and they were continually drawing it from the surface. I think it was in the winter of '74, —it might have been earlier than that; it was in the same year they were so troubled in Boston with the Chestnut Hill Reservoir.

Mr. FitzGerald. That was in '75.

Mr. Ball. Prof. Nichols was examining the water at the Brookline reservoir and, also, all the samples he could obtain throughout the country. I was at Keene stopping at the hotel. They gave me a tumbler of water, as is always the fashion at hotel tables, and I started to drink it, and all I could think of, for smell and for taste, was water in which salt mackerel had been freshened. I wrote to Prof. Nichols at once in regard to the water. He came up to Keene and made a careful examination, and to the astonishment of everybody he found that by lowering the planks so as to draw the water about four feet from the surface the water was perfectly good. In the summer it was just the reverse. You draw it from the surface in the summer time and it was good; you draw it four or five feet down in the winter time and it was perfectly good, while the water above it was bad. So there is no exact hard and fast rule about this thing, no certainty about it. I am convinced by what I know that the true way for a gate house to be constructed for water works of any size is to have a continuous gate so you may have it perfectly under your control to draw your water at any point, either at the surface if it is the best there, or at the bottom if it is best there.

Mr. FitzGerald. I suppose the water was frozen over in the winter, was it not?

Mr. Ball. The explanation Prof. Nichols gave of the matter at Keene was that after the reservoir had been frozen over the air was shut off, so that the water failed to be aerated; and in the course of time it became stagnant on the surface, while below the surface it was good and fresh. That was the explanation which the professor gave of it.

Mr. Richards. We have recently had some trouble with the water in New London, about the first of June. We were then drawing water from the top; I had it changed and drew from about ten feet below the surface and the water became better. Whether it was due to that or not I could not say, but, certainly, the water became better within a week.

Mr. Tidd. I would like to ask Mr. Ball if in drawing from the Worcester reservoir and taking it from the surface, it would reduce the water in the reservoir enough to ascertain whether the water continued good for a certain distance from the level of the water as it fell,—whether the air had any effect upon it as it went down?

Mr. Ball. That appeared to be the result. Sometimes the reservoir would fall several feet during the summer, but just as long as you kept

your supply drawn right close up to the top, the closer the better, the water was good. And I used to try many a time to experiment with it. There was one gate through the reservoir that was connected with the bottom. I used frequently to go there when the water was unobjectionable,—we could taste nothing nor smell anything in it at the city,—and hoist that gate; and standing, I think, as far from where the water ran out as from here to the street, after it had been running for ten or fifteen minutes I could smell distinctly the smell of strong sulphuretted hydrogen, and usually the first run of the water would come out dark colored, looking as if it had been mixed with a large quantity of iron rust. One or two of our physicians, to whom I stated the case, said the phenomenon was undoubtedly due to the presence of iron ore in the bed of the reservoir. The reservoir was entirely and artificial one, and they said that the action of the iron ore on the vegetable matter which accumulated in the water occasioned a decomposition there which really did create sulphuretted hydrogen.

Mr. Tidd. Did they mean iron ore simply or bog iron?

Mr. Ball. There was a large amount of iron ore in the soil and in that neighborhood, but I never found any real bog iron ore in the basin that was flowed over.

Mr. Tidd. Then, if I understand your theory, it would be that if you draw the water from the top, although the water up, say, two or three feet from the bottom might have been bad originally, if you continue reducing your reservoir by drawing from the top the water at the bottom will be good by the time you get to it?

Mr. Ball. Yes, sir; it would be aerated and purified by the action of the air and wind.

Mr. FitzGerald. I have found that to be the case in some of our storage basins. The water four or five feet below the surface would be bad, but as the basin was drawn down the aeration going on, the oxygen coming in contact with the water, purified it, so that by continually drawing from the surface you would get comparatively good water. I should like to know, in the case Mr. Richards speaks of, whether he took specimens of the water to know what the actual condition of the water in the lake was, or whether there might not be something else to account for the trouble.

Mr. Richards. I did not. I took the specimens at the top when it was bad, and we were drawing from the bottom, so I knew it was bad at the bottom then, of course. When I changed it became good, after a time, at the bottom. Where it became good first, whether at the top or the bottom, I don't know.

REPORT

ON THE

CAPACITY OF THE SUDBURY RIVER AND LAKE COCHITUATE WATER SHEDS IN TIME OF DROUGHT.

BY

DESMOND FITZGERALD,

Mem. Amer. Soc. C. E., Resident Engineer.

[We have no apology to offer for reprinting this valuable report, almost verbatim. The edition printed by the city of Boston, Mass. was small, and comparatively few members of the Association will be fortunate enough to obtain a copy. We have ommitted a few pages of details which are somewhat local in their interest, and with the aid of the author have selected the most important tables, not feeling at liberty to reprint them all.—*Editors.*]

BOSTON, May 30, 1887.

WILLIAM JACKSON, *Esq., City Engineer, etc.:*—

SIR,—In answer to your request I send you herewith an estimate of the maximum amount of water that the city of Boston can depend upon from the Sudbury and Cochituate water-sheds in the time of greatest drought.

I have examined the question, *first*, with reference to the period covered by actual measurements of the yield of the Sudbury river and of Lake Cochituate; and, *second*, with reference to the period covered by rainfall records in Boston and vicinity.

Under the first of these heads we have, as data, the monthly flow of the Sudbury river from 1875 to 1886, inclusive, and the yield of the lake by months for a longer period.

So many descriptions have been written of these two sources of supply that I shall refrain from any attempt in the same direction at this time.

It is sufficient to state that there is a connection between the Sudbury aqueduct and one of the brooks supplying the lake, so that, when there is a surplus of water in the Sudbury and a deficiency in the lake, the latter may be reënforced.

This makes the whole system practically one, and both the basins and the lake should be considered together.

It will be seen, however, further on, that in periods of greatest drought there will be no surplus in the Sudbury to use for this purpose after the storage is fully developed by the building of all the reservoirs.

This being the case, I will take, first, the Sudbury river by itself.

At the present time there are four artificial storage-basins. Whitehall pond and Farm pond also exist.

Serveral other available sites have been recently surveyed under your direction; and, after a full examination of the data in each case, I have adopted the following maximum storage. It is somewhat larger than the amount taken by the State Board of Health in their recent estimate, but I believe the storage assumed may be practically and reasonably secured.

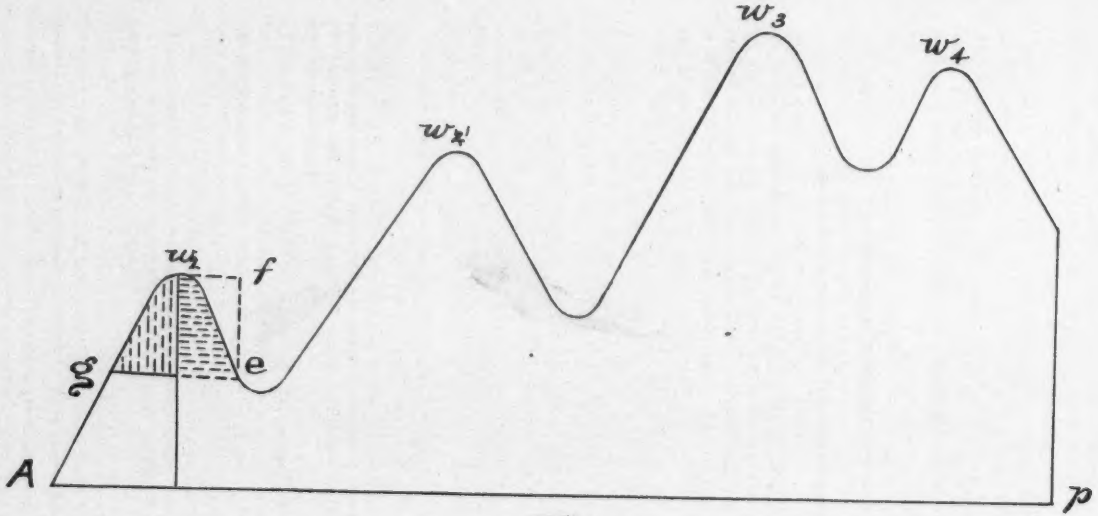


Fig. 1.

It will be seen, by an inspection of Table No. 1, that the maximum amount of storage available on the 75.199 square miles forming the Sudbury water-shed (including Farm pond) has been taken at 8,693,853,175 gallons.

The next step is to determine, from the table of actual flow of the river, as measured, 1875–1886, Table No. 2, the period of greatest drought. This seems to be a simple operation, and it would be so were it not for the facts that there are two periods which give very similar results, viz., 1880 and 1882–1883, and that the lake gives a slightly different result from the river, owing to its flatter water-shed.

The quickest and easiest way to determine the driest period is to plot the monthly flows of the river, and assume a draft-line. (*See Diagram No. 1.*) Measuring graphically the lengths of the ordinates in the periods of deficiency, or when the flow-line runs below the draft-line, and from their sums subtracting any ordinates that may be found in the given period above the draft-line, will give at once the maximum storage required to tide over the period. After one trial the exact draft-line may be found by a simple arithmetical computation. Both this method and the one following treat the storage as a whole ; and, to secure perfect accuracy, the flow and draft must be divided afterwards according to the positions of the several storage-basins and the extent of their respective drainage areas, in order to ascertain whether there will be any waste of water.

On the accompanying profile the flow of the Sudbury river is plotted in a full black line, and a draft-line of 40,000,000 per day assumed for comparative purposes.*

Another very good way of arriving at the period requiring maximum storage is to make a mass diagram, as recommended by Rippl, and there are other advantages which appear in such a diagram after a little study.

[As an aid to a better understanding of the curve the following extract is inserted from *Rippl on Capacity of Storage Reservoirs. Proc. Inst. of C. E., Vol. LXXI, p.* 274.—EDITORS.]

The mass cuvre has the following properties :—

1. For the interval of time between any two points on the axis of abscissas, the difference of the corresponding ordinates is the surplus if positive, or deficiency, if negative during that interval. An ascending part of the curve therefore marks a period during which the quantity in the reservoir is increasing and a descending part of the curve a period during which the quantity in the reservoir is diminishing.

The crests and hollows of the curve indicate those instants of time at which the supply and demand are equal.

2. If a horizontal line is drawn forwards at a crest, for example, the line w^2 f at w^2 Fig. 1, the distance e f of a point e on the descending part of the curve, from the horizontal line, represents the total deficiency within the period represented by w^2 f. To cover this deficiency there must have been previously an equal storage, and e f therefore represents the amount of storage required to meet the deficiency in the period w^2 f.

3. From what previous point of time the storage to meet the deficiency must have commenced is found, by drawing the horizontal line e g back-

*The full red line is the flow of the lake, for the same period, multiplied by four, the drainage area of the lake being about one-fourth that of the Sudbury river. A comparison of these two lines shows that the lake is not quite so "quick" a water-shed, yielding more in the low portions of the profile and less on the summits, but the general form of the two profiles is the same,

wards from e, till it meets an ascending part of the curve. In the period represented by g e the supply and demand are equal. Hence g e may be termed a balancing line.

4. In the mass curve certain hollows may be selected. Lines drawn through these points mark off periods within which the surplus during one part of each period must be stored to balance the deficiency in another part of the period.

5. The quantity of water represented by the vertical projections of the remaining portions of the ascending curve, between the lines, flows away or at all events is not required to meet the demand during the period of time considered.

6. The vertical distances between the lowest and highest crests and hollows in each period are the storage capacities required to equalize the flucuations of supply and demand during those periods.

7. Balancing quantity. The greatest possible vertical distance between a crest and hollow for any one period represents the capacity of the storage reservoir which is sought for.

For if the storage reservoir is capable of equalizing the supply and demand during the period when the vertical distance is greatest, it is sufficient in all other periods.

8. The period in which this greatest vertical distance occurs is therefore the critical period.

9. The ordinates of the mass curve will be positive (drawn upwards) so long as the sum of the surpluses is greater than the sum of the deficiencies up to the point of time considered. When the mass curve crosses the axis of abscissas, the whole previous surplus is exhausted, and if it it falls below the axis of abscissas it is necessary to carry back the curve to some earlier point of time than that at which it was at first started.

* * * * * * * * *

In other words the mass curve will remain above the axis of abscissas so long as the total supply estimated from the beginning of the time considered exceeds the total demand, and only falls below it if the demand exceeds the supply.

10. The mass curve becomes a straight line parellel to the axis of abscissas for any periods during which the supply and demand are exactly equal. Such cases however rarely occur in practice.

It is clear from what has been said that a single period of drought does not afford a safe basis for determining the proper storage capacity of a reservoir. That storage capacity can only be determined with safety by examining a series of such periods.

Hence also it is not the year in which the least total rainfall occurs which gives the measure of the storage capacity required, but the period in which the greatest fluctuation of supply and demand happens. The limitation of the time considered, to a year, is erroneous in principle because the year is, in reference to the question to be solved, an unessential condition. The essential intevals of time are the periods during which the supply and demand are balanced.

Diagram No. 2 has been formed by plotting the differences, monthly, between the assumed draft and the flow. An inspection will show that, with 40,000,000 per day draft, the dry period of 1880 would require 6,300,000,000 gallons storage, while that of 1883 would require only 5,838,000,000 gallons. Thus, 1880 becomes the minimum period of yield. A more careful examination of the two years proves this to be a correct result.

Let us first take 1880. Prior to January, 1881, the measurements for the flow of the river were taken at a temporary dam a short distance below the permanent stone dam. After this time they were taken at the latter place. In order to give a correct result it is neccessary to make a slight correction in the figures as published in the Water Board reports for the different positions of the two weirs. For 1880 the flow was from 78.238 square miles of territory; after that time from 75.199 square miles.

MILLION GALLONS.

1200

1100

1000

900

800

700

600

500

400

300

200

100

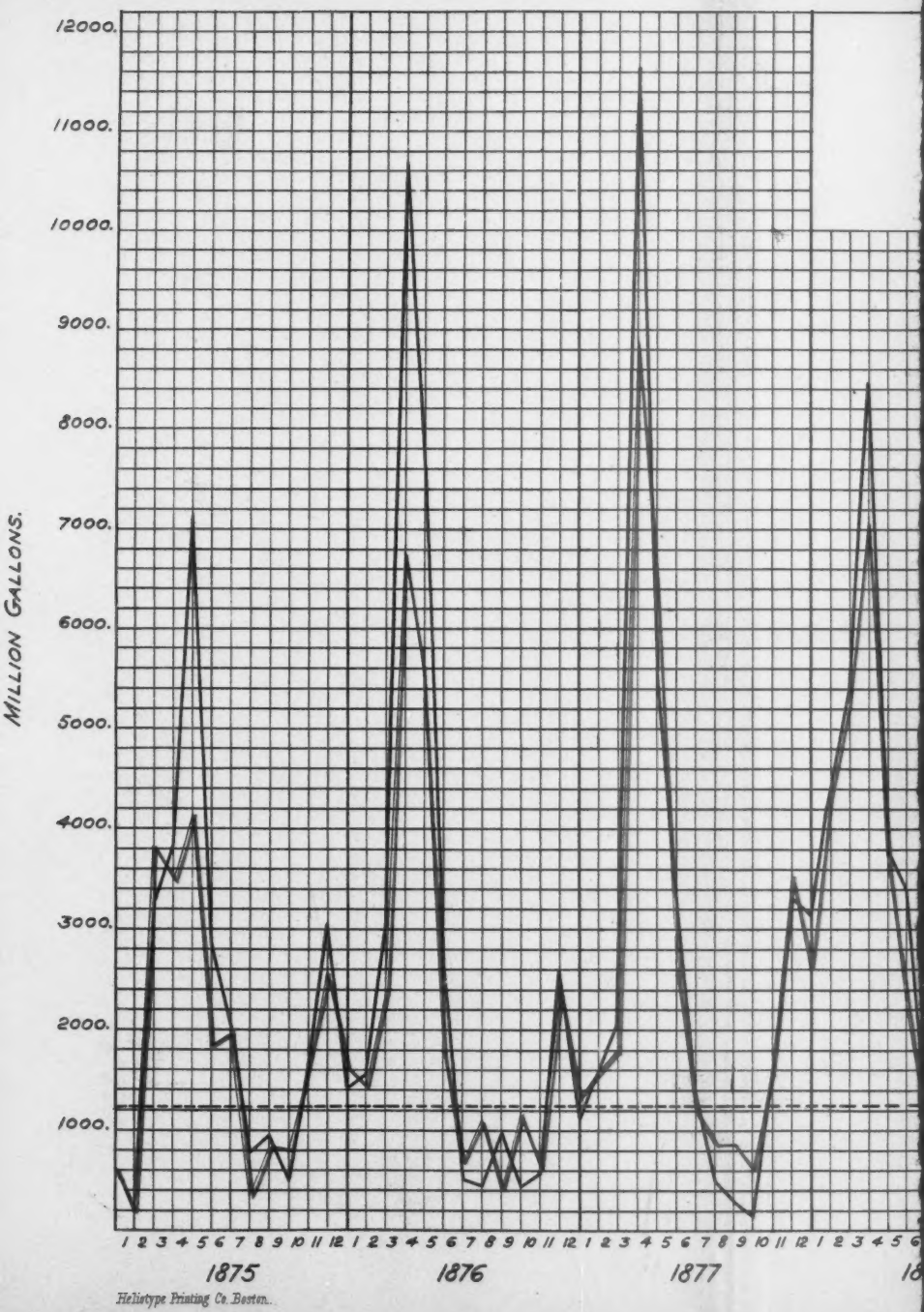


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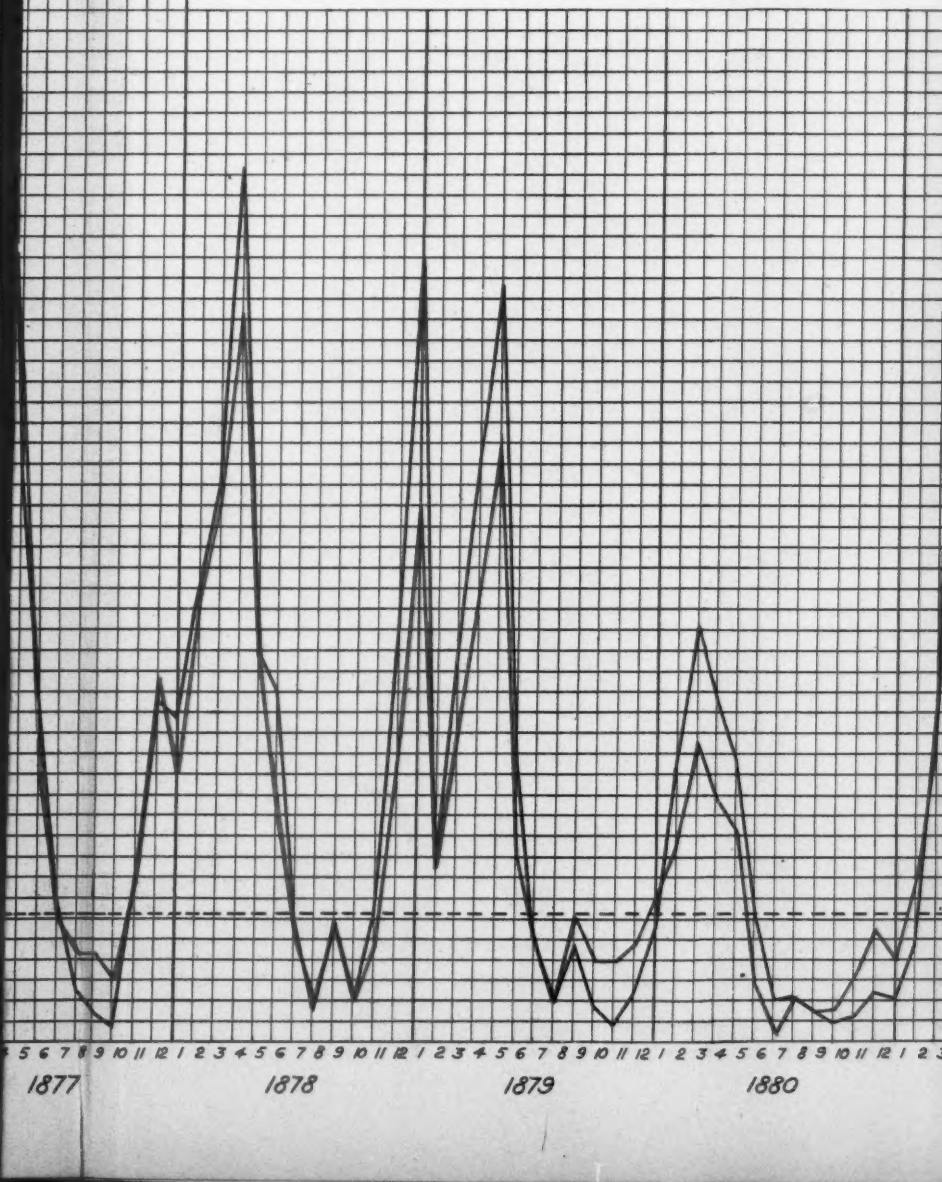
DIAGRAM

MONTHLY YIELD OF SU

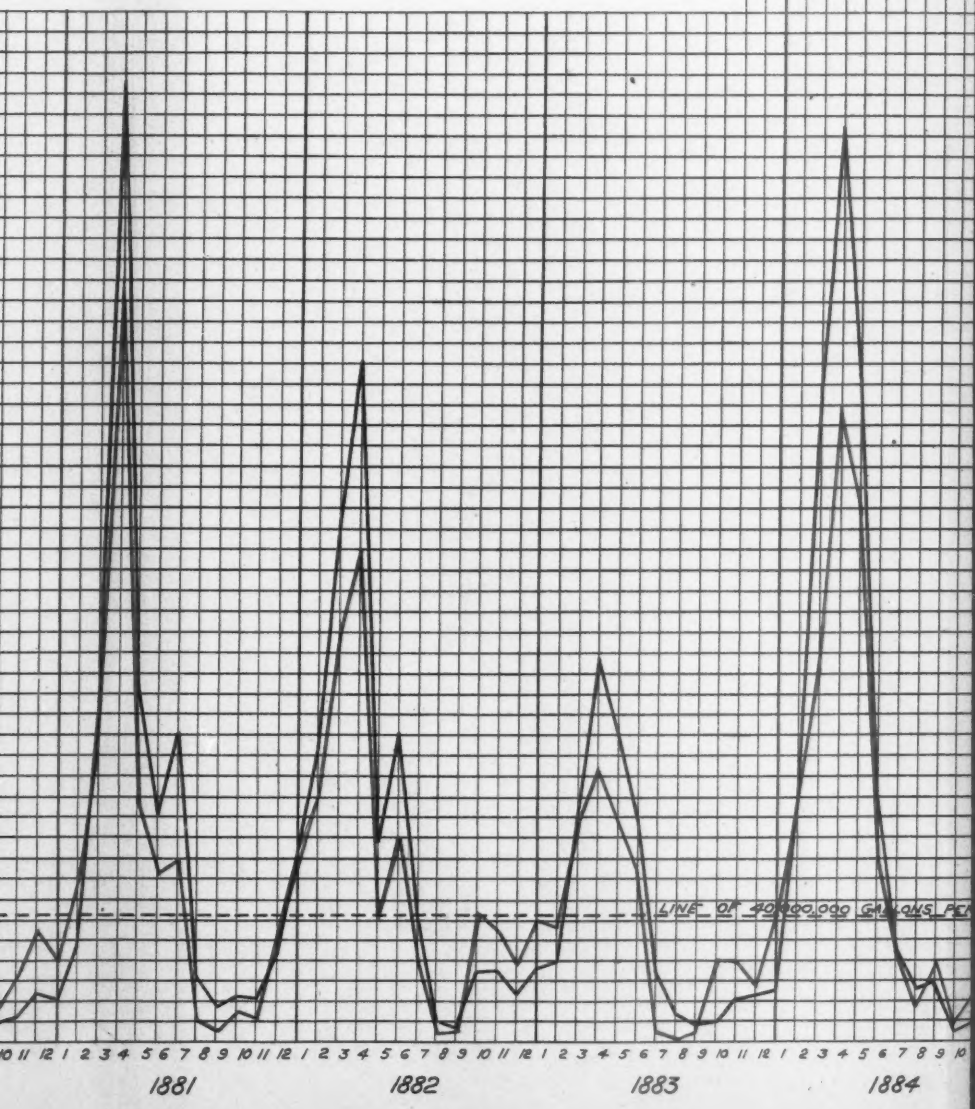
Black Profile shows the actual yie
Red Profile shows the yield of Lal



GRAM No. 1

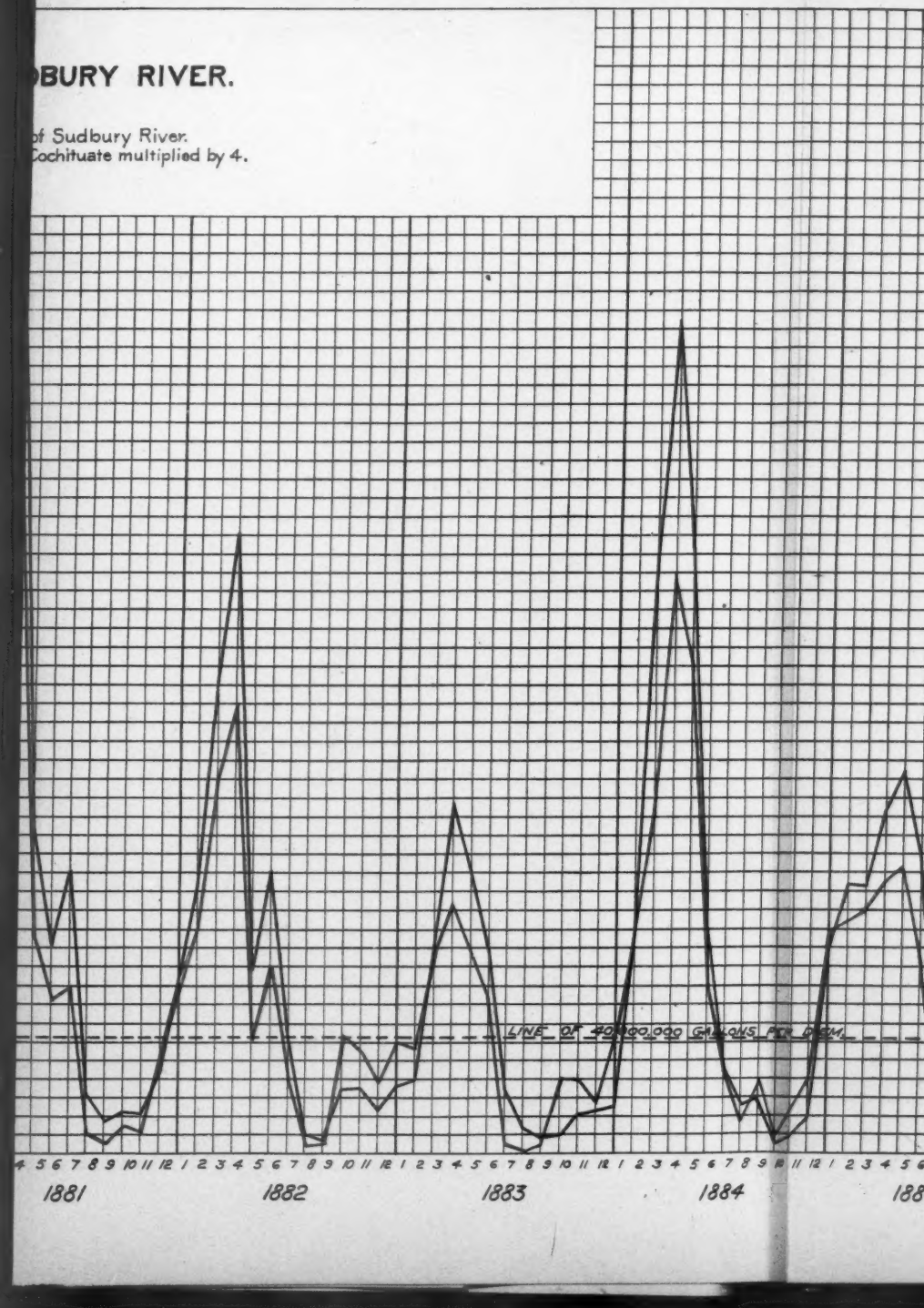
OF SUDBURY RIVER.

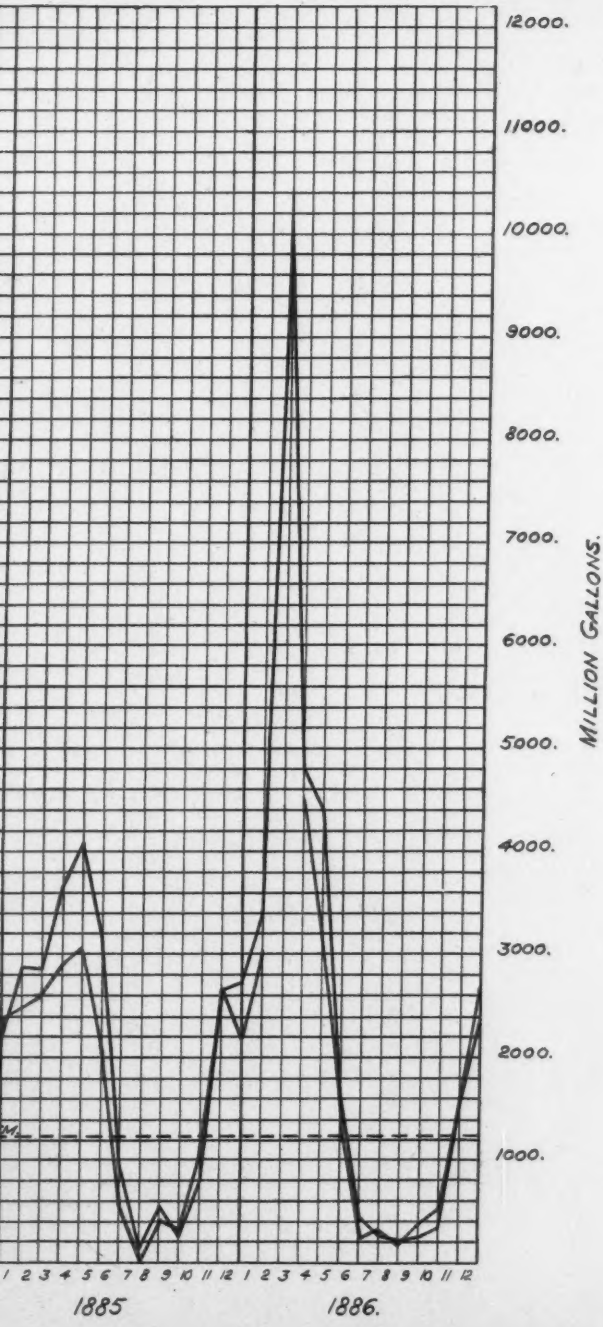
e actual yield of Sudbury River.
yield of Lake Cochituate multiplied by 4.



BURY RIVER.

of Sudbury River.
Cochituate multiplied by 4.




12000.
11000.
10000.
9000.
8000.
7000.
6000.
5000.
4000.
3000.
2000.
1000.
MILLION GALLONS.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1885
1886.

The area of the water-shed above the stone dam is 74.656 square miles, and, adding Farm pond, which enters below the dam, 0.543 square miles, we have the total as above, 75.199 square miles.

Deducting 3.884 per cent. from the quantities as given in Table No. 2, we get the corrected yields exhibited in Table No. 3.

EVAPORATION. It may well be asked whether further corrections should not be allowed for the evaporation from the new water-surfaces. The yield which we are considering has included the evaporation from all but three of the basins in Table No. 1. and these three give a total water-surface of 1,682 acres.

It has been customary to exclude the water-surfaces from drainage-areas in figuring the yield, based on the assumption that the loss by evaporation will be equal to the rain collected on the water-surface. The true solution of the problem would be to determine the difference between the evaporation from the water-surface and from the ground of similar area. Many experiments already made have shown that the evaporation from the ground is very much larger than generally thought; and it can be shown from them that not more than one-third of a given water-surface should be deducted from a water-shed in estimating the yield. However, we have, by actual measurement, in this very case under consideration, a somewhat close approximation to the ratio desired. The measured evaporation in 1880 from a water-surface was as follows—

January . . .	0.90	August	5.34
February . . .	1.20	September	4.04
March . . .	1.80	October	2.79
April . . .	3.10	November	2.60
May . . .	5.22	December	1.20
June . . .	6.46		
July . . .	5.82	Total	40.47 inches.

The rainfall on the Sudbury water-shed for this year was	38.177 inches.
The amount collected	12.487 "
Evaporation from the ground, and other losses	25.690 "

The other losses in the case under discussion are considered to be so small in amount that they may be neglected. Assuming this total loss of 25.69 inches to be due wholly to evaporation, leaves us 39 per cent. of the water-surface to be deducted to give the same loss as from the ground.

If we take one-third of the 1,682 acres of water surface we shall have 560 acres as the quantity to be deducted from the Sudbury-river water-shed. This amount, however, is so small, and is so fully balanced by some other larger factors which have not been considered at all,* that I have made no corrections for the evaporation from the new basins.

With Table No. 3, of monthly flows in 1880, and taking the flow for January, 1881, from Table No. 2, we may divide the flow among the different basins in proportion to their drainage areas, and draw from them as in practice. The results of this operation are shown in Table No. 5.

*Such, for instance, as the increased storage in the ground by raising the water tables.

It is really unnecessary to do this in the case of the year 1880, as it will be seen at a glance that there could be no waste over the lower dam between the beginning and end of the deficiency period. The storege-basins begin to lower in May, 1880, and are practically exhausted in January, 1881, when the flow of the river begins to rise beyond the draft. With a month's supply in reserve, a plan which has been uniformly adopted in all the cases mentioned in this discussion, the Sudbury-river system, when fully developed, would have been good for 43,000,000 gallons per day in 1880, or about 2,000,000 less per day than during the drought of 1882–83, as will be seen farther on.

A shorter and more accurate method of arriving at the result, after having made sure of there having been no waste, is to take the storage, plus the flow, of the river, and divide by the number of days, thus :—

Storage,	8,693,853,175 gallons.
Flow of Sudbury from May '80 to June '81.	4,538,570,560 gallons.
	13,232,423,735 gallons.

divided by 276 days + 31 (for one month's supply) gives 43,102,357 gallons per day, which is the exact net yield.

[Mr. FitzGerald then presents figures relating to the yield of Lake Cochituate during the drought of 1880, with high water taken at its present level and also at a point two feet higher, and puts the daily yield from May 1880 to Jan. 1881 inclusive, with 30 days supply in reserve, at 10,958,673 gallons, with the present high water line.

The total yield of the lake and river are then combined, and with the lake at its present level the figures are 54,061,030 gallons daily with one month's supply of water on hand at the end of the drought. But certain deductions from these figures are to be made, including 1.5 millons daily which must be wasted into the river, which cause Mr. FitzGerald to put the daily supply, with the present storage capacity of the lake, at 48 million gallons during a year like that of 1880. Legislative action will be required to enable the city of Boston to raise the lake 2 feet above its present level and doubt is expressed as to the possibility of securing such action.

The drought of 1882–1883 is then studied in the same thorough manner, and 1880 is shown to have been the worst year, for collection and storage, of any considered. The author points out the inconvenience of the present division of the year between January and December in studying a problem like this one, and says that a water supply year should really begin in November, when the percentage of water collected begins to rise some three fold above that of the preceding months, and which forms the dividing line between deficiency and surplus in the average year.—*Eds.*]

Rainfall Record Previous to 1875.

I come now to the second part of my examination, which extends into the period previous to the measurements of the flow of the Sudbury river, and of which we have only the records of the rainfall.

The Cochituate records start from 1852, and these are the ones to which we should naturally turn ; but, owing to a variety of causes, they are

DIAGRAM No

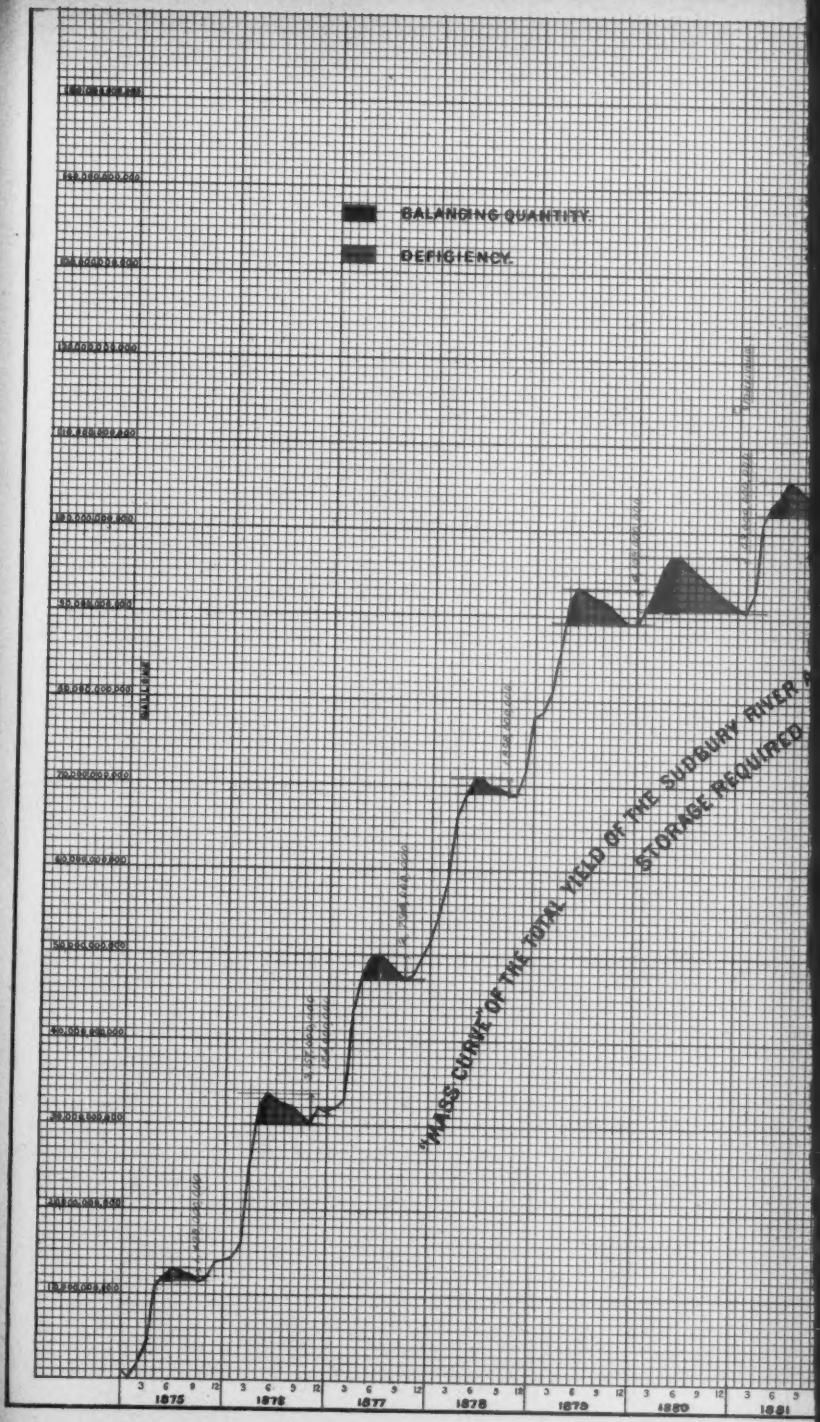
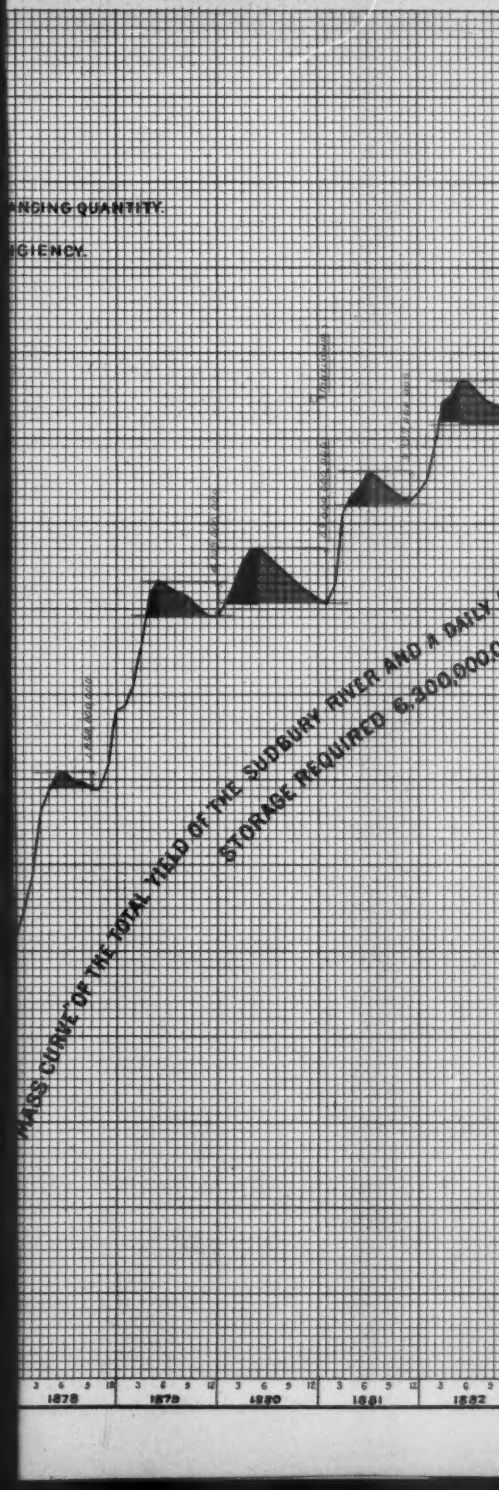

BALANCING QUANTITY.
DEFICIENCY.
"MASS CURVE" OF THE TOTAL YIELD OF THE SUDBURY RIVER
STORAGE REQUIRED
1875
1876
1877
1878
1879
1880
1881

DIAGRAM No. 2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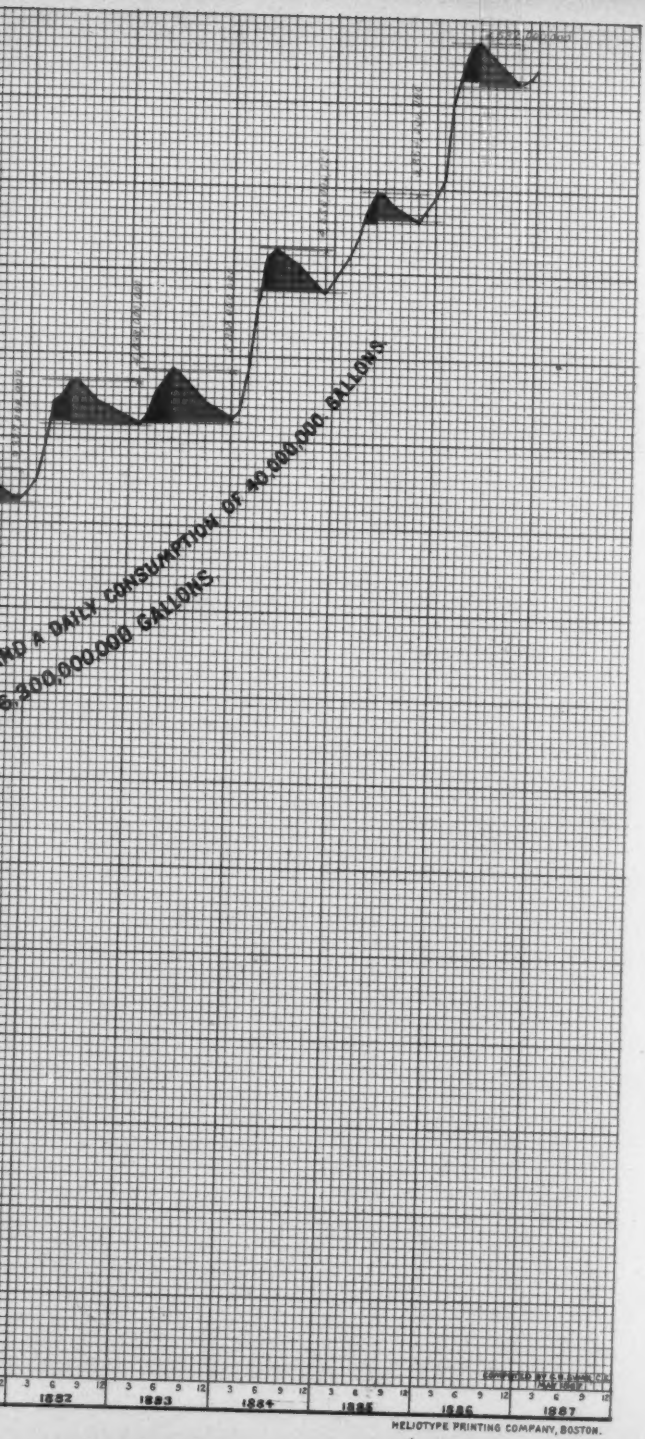

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untrustworthy previous to the year 1872 or thereabouts. They have generally been rejected previous to 1863, as far as the flow of water is concerned, and I have now very good evidence for believing the rainfall to have been incorrectly measured for several years after that date.* For our present purpose, however, this is a matter of small importance except in so far as the tables of percentages collected are concerned, for the reason that there was no serious period of drought between 1846 and 1880.

Fortunately we have twelve or fifteen years of accurate observations from which to ascertain the amount of yield of the Sudbury and Cochituate water-sheds under given conditions of rainfall without making use of the Cochituate records previous to 1872.

It would appear at first glance as rather a singular fact if the short period from 1875–1886, which we have already been considering, should have contained the absolute maximum period of drought; and still more so as it is difficult to select the driest year, for the reason that there are two which give almost identical results. The question may well be asked, Is it probable that the future will give no severer test to our water-supply than the years 1880 and 1882–3?

The longer observations extend back into the past the better we shall be able to judge of what is coming in the future. I have collected a very good table of the monthly distribution of the rainfall in Boston from 1818 to the present year. This will be found in the latter part of the report, together with a number of tables of the rainfall as observed for many years in other places in the vicinity of Boston. I hope these tables will be found useful to hydraulic engineers for other purposes. There is generally considerable uncertainty connected with early rainfall records; but, after the investigations that I have recently made into these matters, I have come to the conclusion that the majority of rainfall records at the present day are somewhat uncertain, and should be accepted only after strong corroborative testimony from other gauges in the neighborhood.

I believe the rainfall record in Table No. 10, from 1818 to 1850, to be as accurate as that from 1850 to 1880. It is, however, generally true that our early rainfall records give from 5 to 10 per cent. less than they should, owing to the gauges being often somewhat elevated above the surface of the ground, or their otherwise imperfect location.

With some exceptions, I have found the original notes kept by Dr. Enoch Hale from 1818 to 1840 for the Rumford fund.

They contain observation, three times a day, of numerous instruments, and show intelligence and care. They have never before been published in monthly form, so far as I can ascertain. (Table No. 11.) The Smithsonian Institution had the yearly results, which were partially published in Schott's tables, and they contain a few small errors. Mr. Jonathan P. Hall kept a gauge from 1821 to quite a recent date, and I have found his results corroborative of those of Dr. Hale during the years when they were observing together.

*In 1886 I had a letter from some one who wrote that he visited the lake during the latter part of the war and found that the gauge in use had a piece of tin soldered on to the outside of the collecting rim and extending upwards for about one foot; that he impressed upon the Superintendent the inaccurate results which were being observed, etc. After a search I found this very gauge in the loft of an old stable, and it is now in my custody. It added about 7 p. c. to the proper area of the gauge, but I have been unable to ascertain how many years this novel device was in use.

Mr. Joseph P. Davis, in his report on the Charles river (City Doc. No. 85, 1874), makes the following pertinent observations on the dry years in Boston and vicinity:—

"The rain records of Boston, Cambridge, Lowell, and other places, show that in a season of great drought the rainfall is not more than 30 inches. Thus, in 1846 the rainfall

In	Boston	was	29.95 inches.
"	Waltham	"	26.90* "
"	Lowell	"	28.03 "
"	Cambridge	"	30.37 "
"	Providence	"	30.51 "

"The rain record of Lowell shows the following years of small rainfall, during the term of twenty-two years previous to 1847:—

In	1825	the	rainfall	at	Lowell	was	28.46* inches.
"	1826	"	"	"	"	32.49	"
"	1834	"	"	"	"	31.78	"
"	1835	"	"	"	"	32.42	"
"	1836	"	"	"	"	35.53	"
"	1837	"	"	"	"	30.86	"
"	1838	"	"	"	"	37.52	"
"	1839	"	"	"	"	38.21	"
"	1840	"	"	"	"	38.70	"
"	1846	"	"	"	"	28.03	"

"The record of Providence gives the following consecutive series of dry years:—

In	1832	the	rainfall	at	Providence	was	39.46 inches.
"	1833	"	"	"	"	33.44	"
"	1834	"	"	"	"	41.92	"
"	1835	"	"	"	"	30.96	"
"	1836	"	"	"	"	37.87	"
"	1837	"	"	"	"	31.62	"
"	1838	"	"	"	"	37.88	"
"	1839	"	"	"	"	36.75	"

In	1822	the	rainfall	in	Boston	was	27.20 inches.
"	1828	"	"	"	"	32.41	"
"	1837	"	"	"	"	33.52	"

"It will be seen that a rainfall of from 27 to 33 inches is no uncommon occurrence, and that cycles of from to to five dry years do have place.

"It will also be noticed that a year of very low rainfall may be preceded by a number of years of drought; thus, the low rainfall of 1837 in Lowell was preceded by three years in which the average rainfall was only 33.24 inches."

The record in the above report of 26.9 inches for Waltham, in 1846, I have ascertained included ten months only, so that this cannot be reciv-ed. That for Lowell for 1825, 28.46 inches, is also untrustworth, as it

*Untrustworthy.

contained nine months only ; so that these two must be rejected. The others, however, are probably correct, and the statements that "rainfalls from 27 to 33 inches are no uncommon occurrence," cannot be otherwise than true.

I have applied a number of the years of very great drought found in the rainfall record of Boston and vicinity to the Sudbury water-shed, working out the yields from assumed percentages of rainfall collected.

I find that there are several periods which give smaller results than the year 1880.

The greatest drought, however, which I have found was that of 1822, and as any storage that would safely carry the city through this period, 1821-2, would do so easily in all the others, it is to this year, and the immediate months at each end of it, to which I desire more particularly to call attention.

The rainfall for 1822 was 27.2 inches, as recorded by Dr. Hale. I have examined his rains in detail, and find that they agree with the state of the sky three times a day as reported by him ; also that the snow was melted and measured in the usual manner.*

The snow is often left entirely out of some early records,† and it is very necessary to find out if it has been measured. Dr. Hale's notes show him to have been a careful observer, and that he made a special study of rain-gauge observations.

I next searched among the local papers for some external evidences of the dry conditions which must have prevailed with such a scarcity of rain, and I have found that serious droughts were reported all over the country. Mills which had never stopped grinding corn for lack of water were obliged to do so this year, and springs were reported lower than ever before known in the memory of man. Cattle-driving in the West was stopped by scarcity of provender, etc. In some parts of Pennsylvania, Virginia, Maryland "almost everything was destroyed by the drought."

The next step after ascertaining the distribution of the rains is to plot a hypothetical flow of the Sudbury river and Cochituate areas, based on the percentages collected under similar conditions in other years when the flow was measured. The difficulty consists in selecting the proper percentages collectible to apply to each month's rainfall.

Experience has taught us that as a general rule the drier the year the smaller the average percentage collected. This percentage depends, however, almost entirely upon the distribution of the rains. Heavy summer rains and light winter ones give the minimum percentage, and *vice versa*. If, however, we select percentages which we know have always been found smaller in years of similar distributions there can be no doubt that the result will be large enough. This course has been adopted in the case of the drought of 1822, and I think no one of experience in these matters will feel otherwise than that the flow is probably too large. The following table gives the rainfall and per cents adopted:—

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*Notwithstanding the apparent accuracy of Dr. Hale's observations, I have generally found that gauges located in the gardens of the Boston houses give results about 5 per cent. too small. It is largely for this reason that I have taken liberal percentages of collection.

†As the case with the early Charlestown records.

	1821.		1822.		1823.	
	Rainfall.	Per cents collected.	Rainfall.	Per cents collected.	Rainfall.	Per cents collected.
Jan	1.41	36	1.29	59.	4.14	45
Feb	4.42	56	2.34	76.8	4.58	76.8
March	2.53	175	2.02	75.8	7.62	116.3
April	4.90	104	2.99	66.6	1.24	125.
May	4.84	67	0.87	150.	etc.	etc.
June	2.79	21	3.54	18.		
July	2.35	8.5	4.32	5.1		
Aug.	1.58	10.9	1.20	5.4		
Sept	4.73	7.	2.15	8.9		
Oct.	2.29	18.6	2.53	6.0		
Nov.	3.12	25.0	2.58	11.		
Dec.	1.93	45	1.46	11.3		
Total of averages.	36.89	48	27.20	41.1		

I have already alluded to the special characteristics of the droughts of 1880 and 1882–3. It will be seen, by an inspection of the above rainfall and the plot of the flow of the river calculated from the percentages, that that the drought of 1821–2 was very similar to that of 1882–3, and that it was much more severe. The period of Deficiency extended from June 1821, to Jan., 1823, and, with such an unfavorable distribution of the rains, the flow of the streams must have been smaller than during any drought that has occurred since that date.

The total flow of the Sudbury river on the above basis I have estiminated could not have been more than

	15,788,000,000	gallons.
Storage	8,693,853,175	"
Total	24,481,853,175	"

which, divided by 579+31=610 days=40,134,185 gallons per day, if there was no waste. In Table No. 7 the basins had been filled and drawn from as in the previous cases, and it is there shown that there was no waste.

Lake Cochituate, 1821-2.

Present Flow-line.

The yield of Lake Cochituate has been estimated on the same basis as the Sudbury river, and it has been found to give,—

From June, 1821, to Jan., 1823,	4,130,085,103	gallons.
Capacity from grades 125 to 134.36,	1,903,953,000	"
Total,	6,034,038,103	"

Which, divided by 579+31=610 days=9,891,865 gallons daily.

Lake Raised Two Feet.

If the lake is raised 2 ft. the flow and storage will be increased to 6,571,655,603 gallons, which, divided among 610 days, equals 10,773,200 gallons per day.

Both these estimates give one month's supply on hand at the end of the period, as in former cases.

Net Yield of River and Lake, 1821–2

Yield of Sudbury river,	40,134,185	gallons.	
" Lake Cochituate,	9,891,865	"	
Total	50,026,050	"	daily.
Less water used by towns etc.,	6,000,000	"	"
Net yield,	44,026,050	"	"

Lake Raised Two Feet.

Yield of Sudbury river,	40,134,185	gallons.	
" Lake Cochituate,	10,773,200	"	
Total	50,907,385	"	daily.
Less water used by towns, etc.,	6,000,000	"	"
Net yield,	44,907,385	"	"

Summary.

In view of the liberal estimate that was made in computing the hypothetical flow of the river I do not think it would be safe for the city to depend upon a greater supply than forty four millions of gallons daily from the Sudbury and Cochituate sources during a long term of years. It should also be stated that the foregoing estimates have been made on the supposition that the water of all the basins was of good quality, and fit for domestic use; but experience has shown that it is hardly safe to rely on such a condition of things.

English Observations.

In the course of my investigation of this question of the possible minimum yield of these water-sheds I have had occasion to look somewhat carefully into the record of the rainfall in England. The tables of that country cover a period of about two hundred years. I do not propose to bring the results of these examinations into this report; but as the similarity of the rainfall in Boston and Liverpool has been several times alluded to in the many reports of the Boston Water Works, I may simply say that, if the future has anything like the same droughts in store for us that have visited England in the past, the foregoing estimates of the yields of the Sudbury and Cochituate basins will be found to be much too liberal. I cannot find, however, that during the sixty or seventy years of rainfall observations in Boston there is any indication of anything like such fluctuations as have occurred in England, and that it is improbable that a *severe* drought extending over more than one winter or two dry years will occur.

Very truly yours,

DESMOND FITZGERALD.

TABLE No. 1.

Areas and Capacities of present and proposed Storage-Basins on Sudbury River and its Tributaries.

Name.	Area of water-s'rface in acres,	Water-shed in square miles, in cluding water-surfaces.	Storage capacity in gallons.	Grades above tide marsh level.
Farm Pond.....	163	0.543	165,500,000	146 to 149.25[1]
Basin, No. I.....	143	1.840	288,400,000	152 " 159.29[2]
" " II.....	134	28.279*	479,700,000	152 " 167.12[3]
" " IV.....	167	6.066	1,416,000,000	169 " 214.21[4]
Indian Brook, No. V.	235	5.902	1,603,000,000	244 " 295.0 [5]
Whitehall P'd, No. VI.	633	4.892	1,741,253,175	331.91[6]
Basin, No. III.....	276	27.677	1,074,600,000	156 " 175.24[7]
" " VII.....	1,280		1,925,400,000	212 " 248.0 [8]
Total.....	1,280	75.199	8,693,853,175	

*Exclusive of contributing water-sheds from other basins.
[1]High-water line.
[2]Top of second flash-boards.
[3] " " " "
[4]Crest of overflow.
[5]High-water line.
[6]Raised four feet above present high-water line.
[7]Crest of overflow.
[8]Approximate high-water line.

TABLE No. 2.

Monthly Yield of the Sudbury River in gallons, 1875 to 1887.

WATER-SHED FROM 1875 TO 1878, INCLUSIVE,=77.764 SQUARE MILES; IN 1879 AND 1880=78.238 SQUARE MILES; FROM 1881 TO 1887=75.199 SQUARE MILES.

Month.	1875.	1876.	1877.	1878.	1879.	1880.
January	248,000,000	1,550,300,000	1,586,900,000	4,362,100,000	1,698,200,000	2,716,000,000
February	3,257,800,000	3,064,500,000	2,066,900,000	5,367,900,000	3,747,900,000	4,054,400,000
March	3,867,200,000	10,691,100,000	11,604,100,000	8,454,400,000	5,651,400,000	3,332,200,000
April	7,113,200,000	7,680,400,000	5,584,100,000	3,793,200,000	7,313,700,000	2,743,000,000
May	2,863,100,000	2,744,000,000	3,354,200,000	3,361,600,000	2,701,400,000	1,247,000,000
June	2,029,100,000	517,500,000	1,393,000,000	1,179,800,000	970,200,000	411,700,000
July	774,700,000	441,100,000	486,060,000	309,500,000	381,700,000	427,700,000
August	954,000,000	976,900,000	291,890,000	1,146,300,000	958,300,000	288,200,000
September	483,800,000	430,200,000	139,000,000	375,100,000	330,300,000	188,400,000
October	1,557,500,000	563,000,000	1,522,400,000	1,244,300,000	171,500,000	246,500,000
November	3,038,000,000	2,537,800,000	3,307,300,000	3,949,000,000	482,500,000	481,700,000
December	1,407,300,000	1,093,100,000	3,108,900,000	7,658,800,000	1,121,800,000	424,800,000
Totals	27,593,700,000	32,309,900,000	34,444,750,000	41,202,000,000	25,528,900,000	16,561,600,000

TABLE No. 2.—*Concluded.*

Month.	1881.	1882.	1883.	1884.	1885.	1886.
January	966,900,000	2,892,200,000	780,500,000	2,319,900,000	2,878,500,000	3,405,300,000
February	3,255,500,000	5,060,300,000	2,174,500,000	6,197,300,000	2,850,900,000	10,108,000,000
March	9,333,600,000	6,617,900,000	3,755,000,000	8,824,300,000	3,665,600,000	4,798,800,000
April	3,487,700,000	1,956,800,000	3,044,500,000	6,437,300,000	4,094,800,000	4,392,400,000
May	2,249,600,000	3,010,900,000	2,185,300,000	2,402,100,000	3,114,400,000	1,679,100,000
June	3,017,800,000	1,193,300,000	676,900,000	939,000,000	950,700,000	458,100,000
July	644,300,000	201,100,000	268,900,000	521,500,000	144,700,000	269,700,000
August	345,200,000	128,900,000	183,000,000	598,500,000	560,200,000	219,600,000
September	444,900,000	691,500,000	205,900,000	99,100,000	273,100,000	264,900,000
October	432,600,000	697,700,000	433,200,000	193,800,000	782,500,000	339,700,000
November	891,000,000	472,300,000	461,700,000	395,300,000	2,656,300,000	1,518,700,000
December	1,806,900,000	733,600,000	451,100,000	2,156,000,000	2,736,700,000	2,377,000,000
Total	26,876,000,000	23,656,500,000	14,620,500,000	31,084,100,000	24,718,400,000	29,831,300,000

TABLE No. 3.

TABLE OF CORRECTED YIELD OF THE SUDBURY RIVER FOR THE YEAR 1880.

1880.	*Gallons.*
January	2,610,510,560
February	3,896,927,104
March,	3,202,777,352
April	2,636,461,880
May	1,198,566,520
June	395,709,572
July	411,088,132
August	277,006,312
September	181,082,544
October	236,925,940
November	462,990,772
December	408,300,768
Total	15,918,347,456

Table No. 8.

Rainfall, rainfall collected, and per cent. collected on the Sudbury River Water-shed.

Rainfall in Inches.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.	Four mos. July-Oct.
1875	2.42	3.15	3.74	3.23	3.56	6.24	3.57	5.53	3.43	4.85	4.83	0.94	45.49	17.38
1876	1.83	4.21	2.43	4.197	2.763	2.040	9.134	1.720	4.614	2.241	5.764	3.620	49.563	17.709
1877	3.216	0.739	8.357	3.435	3.702	2.425	2.951	3.682	0.323	8.515	5.803	0.870	44.018	15.471
1878	5.632	5.973	4.689	5.790	0.956	3.884	2.971	6.937	1.291	6.417	7.024	6.367	57.931	17.616
1879	2.478	3.562	5.140	4.716	1.579	3.789	3.933	6.509	1.878	0.809	2.682	4.344	41.419	13.129
1880	3.566	3.980	3.315	3.105	1.836	2.138	6.273	4.008	1.603	3.740	1.785	2.828	38.177	15.624
1881	5.558	4.646	5.730	2.000	3.511	5.395	2.350	1.358	2.617	2.055	4.091	3.958	44.169	9.280
1882	5.951	4.546	2.649	1.824	5.066	1.664	1.769	1.667	8.741	2.074	1.147	2.296	39.394	14.251
1883	2.81	3.865	1.78	1.845	4.185	2.40	2.68	0.735	1.52	5.60	1.81	3.55	32.78	10.535
1884	5.085	6.545	4.72	4.405	3.47	3.445	3.665	4.65	0.855	2.48	2.645	5.17	47.135	11.650
1885	4.71	3.865	1.07	3.605	3.485	2.865	1.425	7.185	1.425	5.095	6.095	2.72	43.545	15.13
1886	6.365	6.28	3.61	2.225	2.995	1.465	3.265	4.10	2.905	3.235	4.645	4.975	46.065	13.505
Averages	4.135	4.280	4.352	3.365	3.092	3.146	3.666	4.007	2.600	4.001	4.027	3.470	44.141	15.274

TABLE No. 8.—*Continued.*

RAINFALL COLLECTED IN INCHES.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.	Four mos. July-Oct.
1875	0.184	2.411	2.862	5.263	2.119	1.501	0.573	0.706	0.358	1.152	2.248	1.041	20.418	2.789
1876	1.147	2.282	7.911	5.683	2.031	0.383	0.326	0 723	0.318	0.417	1 878	0.809	23.908	1.784
1877	1.174	1.529	8.586	4.132	2.482	1.031	0.360	0.216	0.103	1.127	2.447	2.300	25.487	1.806
1878	3.228	3.972	6.256	2.807	2.487	0.873	0.229	0.848	0.277	0.921	2.922	5.067	30.487	2.275
1879	1.249	2.756	4.156	5.379	1.987	0.713	0.281	0.705	0.243	0.126	0.355	0.825	18.775	1.355
1880	2.048	3.057	2.513	2.069	0.940	0,310	0.322	0.217	0.142	0.186	0.363	0.320	12.487	0.867
1881	0.729	2.455	7.038	2.630	1.686	2,276	0.486	0.260	0.336	0.326	0.672	1.363	20.257	1.408
1882	2.181	3.816	4.991	1.476	2.271	0.900	0.152	0.097	0.522	0.526	0.356	0.553	17.841	1.297
1883	0.588	1.640	2.832	2.295	1.648	0.511	0.203	0.138	0.155	0.326	0.348	0.340	11.024	0.822
1884	1.751	4.673	6.654	4.854	1.811	0.708	0.393	0.452	0.074	1.146	0.298	1.626	23.440	1.065
1885	2.17	2.149	2.764	3.088	2.348	0.724	0.108	0.422	0.208	0.590	2.003	2.063	18.637	1.328
1886	2.568	7.623	3.619	3.313	1.266	0.346	0.203	0.166	0.200	0.256	1.145	1.793	22.498	0.825
Averages	1.585	3.197	5.015	3.582	1.923	0.856	0.303	0.413	0.245	0.508	1.253	1.558	20.438	1.469

TABLE No. 8.—*Concluded.*

PERCENTAGE OF RAINFALL COLLECTED.

Year	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly.	Amounts. July-Oct.
1875	7.6	76.5	76.5	162.9	59.5	24.0	16.0	12.8	10.4	23.8	46.5	110.7	44.9	16.0
1876	62.7	54.2	106.5	135.4	73.5	18.8	3.6	42.0	6.9	18.6	32.6	22.3	48.2	10.1
1877	36.5	206.9	102.7	120.3	67.0	42.5	12.2	5.9	31.9	13.2	42.2	264.4	57.9	11.7
1878	57.3	66.5	133.4	48.5	260.2	22.5	7.7	12.2	21.5	14.3	41.6	89.0	52.6	12.9
1879	50.4	77.4	80.9	114.1	125.8	18.8	7.1	10.8	12.9	15.6	13.2	19.0	45.3	10.3
1880	57.4	76.8	75.8	66.6	51.2	14.5	5.1	5.4	8.9	5.0	20.3	11.3	32.7	5.6
1881	13.1	52.8	122.8	131.5	48.3	42.2	20.7	19.2	12.8	11.0	16.4	34.4	45.9	15.2
1882	36.6	83.9	188.4	80.9	44.8	54.1	8.6	5.8	6.0	25.4	31.0	24.1	45.3	9.1
1883	20.9	42.4	159.1	124.4	39.4	21.3	7.6	18.8	10.2	5.8	19.2	9.6	33.6	7.8
1884	34.4	71.4	141.0	110.2	52.2	20.6	10.7	9.7	8.7	5.9	11.3	31.4	49.7	9.1
1885	46.1	55.6	258.3	85.7	67.4	25.3	7.7	5.9	14.4	11.6	32.9	75.9	42.8	8.8
1886	40.4	121.4	100.2	148.9	42.3	23.6	6.2	4.0	6.9	7.9	24.7	36.0	48.8	6.1
Averages	38.3	74.7	115.2	106.4	62.2	27.2	8.3	10.3	9.4	12.7	31.1	44.9	46.3	10.3

TABLE NO. 10.

BOSTON RAINFALL.

1818–1823. Dr. Enoch Hale. Carefully collated from original records. Snow melted and measured.
1823–1866. Jonathan P. Hall. From 1823 to 1856 taken from Am. Acad. Arts and Sciences Memoirs. Vol. VI., n. s., pp. 229, 308.*
1866–1885. Supt. of Sewers.† 1885–1887. Boston Water-Works.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	For the Year.
1818...	2.64	3.49	4.05	6.15	5.96	3.47	4.08	0.46	7.81	2.11	1.91	0.86	42.59
1819...	0.70	2.27	6.21	3.74	3.06	3.56	2.02	4.38	5.29	1.40	1.22	1.03	35.48
1820...	3.12	4.25	4.90	0.45	5.08	3.42	4.19	5.15	2.43	5.39	3.00	2.80	44 18
1821...	1.41	4.42	2.53	4.90	4.84	2.79	2.35	1.58	4.73	2.29	3.12	1.93	36.80
1822...	1.29	2.34	2.02	2.99	0.78	3.54	4.32	1.20	2.15	2.53	2.58	1 46	27.20
1823...	3.00	4.57	7.72	2.21	6.40	0.93	5.74	1.98	1.95	3.95	1.92	6.93	47.30
1824...	3.95	5.99	1.81	4.72	1.43	1.60	0.88	3.68	6.43	1.01	1.72	2.80	36.02
1825...	2.79	3.43	4.70	0.37	1.36	4.77	1.24	5.62	2.66	3.21	0.81	4.38	35.34
1826...	2.55	1.48	3.81	1.50	0.25	3.85	2.90	12.10	3.03	3.80	2.31	3.56	41.14
1827...	3.92	2.97	2.51	4.75	5.34	2.56	2.59	4.88	4.81	5.28	5.71	3.59	48.91
1828...	2.15	2.79	1.84	2.00	4.67	1.59	4.58	0.37	3.82	2.79	5.55	0.26	32.41
1829...	4.93	5.62	4.30	3.45	2.71	1.64	6.98	4.95	2.62	1.65	5.74	2.26	46.85
1830...	2.36	1.63	3.51	1.21	3.93	3.46	4.90	2.64	5.65	2.38	5.32	5.96	42.95
1831...	4.44	3.68	3.07	6.97	3.65	4.32	5.53	5.57	3.83	4.42	3.20	2.93	51.61
1832...	4.47	3.74	2.65	5.56	7.27	0.50	3.41	6.14	2.07	2.46	3.57	4.85	46.69
1833...	2.96	2.53	2.71	2.30	1.03	3.23	2.01	0.82	2.88	6.00	5.53	5.86	37.86
1834...	1.39	1.13	0.96	2.93	6.33	3.00	7.71	2.47	3.71	4.62	2.90	2.36	39.60
1835...	3.25	1.37	4.27	4.54	2.07	2.74	9.07	2.89	1.31	1.87	2.08	2.40	37.86
1836...	8.84	3.57	2.90	1.58	1.85	4.33	2.12	1.53	0.54	4.04	5.43	4.13	40.86
1837...	4.10	4.14	3.02	3.07	5.79	2.98	1.80	1.67	0.56	1.58	2.35	2.46	33.52
1838...	3.07	2.77	3.09	2 62	3.32	2.55	1.20	4.26	9.87	5.02	3.95	0.80	42.52
1839...	0.98	3.11	1.18	7.73	4.27	2.25	3.32	5.70	2.00	2.50	1.71	6.35	41.10
1840...	3.12	2.57	4.55	4.60	2.23	2.78	2.93	4.00	2.12	4.48	11.63	4.15	49.16
1841...	6.00	1.60	3.50	8.82	1.90	1.95	2.10	4.20	2.86	3.80	4.55	5.77	47.05
1842...	0.80	3.20	3.35	3.50	2.90	5.30	1.82	4.44	3.25	0.80	4.45	5.30	39.11
1843...	2.20	6.08	6.17	3.88	1.60	4.61	2.15	6.88	0.98	4.82	3.40	3.92	46.69
1844...	3.68	2.42	6.00	0.20	2.72	1.40	2.17	2.62	3.53	5.80	3.15	3.85	37.54
1845...	4.58	4.25	3.83	1.23	2.82	2.05	3.28	1.82	2.23	4.00	10.25	5.98	46.32
1846...	3.12	2.95	2.73	1.23	2.02	2.25	2.51	1.80	1.30	1.35	4.17	4.52	29.95
1847...	3.28	4.79	4.77	2.20	2.03	4.09	2.65	6.45	6.04	1.05	5.12	3.95	46.93
1848...	2.30	3.90	4.05	1.40	6.30	1.73	1.35	3.10	3.55	5.10	2.25	5.95	40.98
1849...	0.35	1.15	7.35	0.90	3.10	1.45	0.85	6.25	1.25	8.10	5.50	4.05	40.30
1850...	4.59	2.52	5.32	4.82	6.63	2.77	2.70	5.30	7.15	2.10	3.32	6.76	53.98

*Hall's gauge was 18 in. high, 12 in. diameter, and located 90 feet above tide-marsh. The snow was melted and measured.
†The Sewer and Water Works gauges are 14.85 in. diameter, and the collections are weighed.

TABLE No. 10.—*Concluded.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	For the Year.
1851...	1.30	4.20	3.88	9.37	3.31	1.80	3.09	1.27	3.50	4.43	5.51	2.65	44.31
1852...	4.85	2.85	4.45	10.18	1.95	2.35	3.28	7.63	1.65	2.19	3.47	3.09	47.94
1853...	2.44	5.30	2.27	3.78	5.63	0.30	3.64	9.40	3.80	3.92	4.43	3.95	48.86
1854...	2.91	4.87	2.84	6.63	4.33	2.47	3.70	0.58	3.86	2.08	6.80	4.64	45.71
1855...	7.22	4.67	1.18	4.28	1.20	3.09	4.15	1.46	1.13	4.61	5.27	5.93	44.19
1856...	5.32	0.80	1.33	4.37	7.10	2.90	4.02	11.11	4.90	2.70	3.33	4.28	52.16
1857...	5.36	2.45	3.09	10.83	5.57	2.02	5.53	7.18	2.56	4.50	2.52	5.26	56.87
1858...	3.28	2.30	2.18	5.18	3.89	8.09	4.56	7.03	5.02	3.03	3.38	4.73	52.67
1859...	5.93	4.05	7.64	3.36	3.63	7.89	1.58	4.72	4.40	3.28	3.75	6.47	56.70
1860...	1.89	3.85	2.19	1.73	2.35	8.01	5.90	4.30	7.35	2.66	5.37	5.86	51.46
1861...	6.04	3.57	7.48	5.89	2.97	3.64	2.76	6.04	1.77	2.06	4.90	2.35	50.07
1862...	8.30	3.29	4.70	1.97	2.70	6.78	7.33	4.20	5.61	4.85	8.32	3.01	61.06
1863...	4.51	4.54	6.42	9.08	2.82	2.56	12.38	5.64	3.12	3.83	6.48	6.34	67.72
1864...	3.87	1.43	11.75	4.72	3.31	1.47	1.90	4.17	2.00	4.80	4.00	5.28	49.30
1865...	4.47	5.08	4.83	2.57	6.90	2.83	4.26	1.42	0.62	6.21	4.46	4.18	47.83
1866...	3.73	5.28	4.70	2.03	5.04	3.41	5.42	3.87	5.90	2.72	3.74	4.86	50.70
1867...	6.06	6.55	6.12	2.52	4.11	2.74	4.76	10.78	0.44	6.76	2.32	2.48	55.64
1868...	6.09	1.88	5.04	6.94	10.38	3.79	1.10	7.53	11.95	1.78	5.31	2.32	64.11
1869...	4.03	9.98	8.74	2.05	6.88	4.44	3.30	2.19	5.18	6.71	3.74	9.04	66.28
1870...	8.16	7.03	4.88	8.42	2.58	7.59	4.01	1.57	0.67	6.80	4.40	3.62	59.73
1871...	2.77	3.72	4.68	4.23	5.69	5.67	2.87	3.31	1.37	5.51	5.38	3.13	48.33
1872...	2.43	2.68	3.98	3.24	3.95	4.81	4.48	10.48	7.37	4.98	4.64	5.00	58.04
1873...	6.69	3.74	4.54	3.81	4.92	0.65	3.25	6.46	2.78	5.43	7.34	5.33	54.94
1874...	4.30	4.02	1.64	8.36	3.72	2.91	2.70	6.48	1.66	1.02	2.58	1.70	41.09
1875...	3.24	3.62	5.76	4.46	3.89	7.73	3.84	3.50	3.32	5.06	5.62	0.97	51.01
1876...	1.89	5.24	8.25	5.61	3.14	2.16	6.50	1.82	3.62	2.13	9.82	5.01	55.19
1877...	4.03	1.20	9.08	3.82	3.58	3.05	2.58	5.68	0.53	8.19	8.36	1.05	51.15
1878...	7.30	6.08	5.37	5.88	0.92	2.06	3.63	6.50	2.32	6.10	7.11	5.62	58.89
1879...	2.74	3.54	4.31	6.97	1.16	5.62	3.43	6.45	1.86	0.80	3.53	4.64	45.05
1880...	3.23	4.73	3.85	3.28	1.86	0.63	7.52	2.87	2.30	3.41	2.07	3.14	38.89
1881...	5.59	5.15	6.94	2.36	3.59	7.01	3.51	1.17	2.52	2.86	4.42	4.10	49.22
1882...	4.66	6.35	3.57	2.61	5.80	1.74	4.01	1.69	11.47	2.30	1.74	2.48	48.42
1883...	4.04	3.55	2.14	2.95	3.94	2.57	2.51	0.34	1.38	6.34	2.07	3.73	35.56
1884...	5.71	7.19	6.25	4.88	3.32	4.21	5.33	5.30	0.23	3.34	3.19	4.91	53.86
1885...	5.21	2.88	1.21	3.62	4.35	3.38	1.40	7.22	1.60	5.67	5.53	2.00	44.07
1886...	7.04	7.38	3.76	2.52	3.96	1.30	2.09	3.98	2.94	3.06	3.73	4.71	46.47
Totals	268.96	261.67	296.42	283.02	260.08	227.22	253.77	302.24	238.31	258.42	298.05	272.62	3,220.78
Means	3.90	3.79	4.29	4.10	3.77	3.29	3.68	4.38	3.45	3.75	4.32	3.95	46.67

TABLE No. 10.

PROVIDENCE RAINFALL.

The following monthly and annual depth of rain and melted snow, expressed in inches, was observed and recorded from 1832 to 1876, inclusive, at College Hill by the late President Alexis Caswell, of Brown University. Since 1876 it has been observed and recorded at Hope Reservoir.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	For the Year.
1832...	3.87	4.25	3.20	3.33	4.14	0.33	1.82	3.92	3.50	2.01	3.46	5.63	39.46
1833...	1.71	1.55	1.97	3.17	1.99	4.11	1.11	2.15	1.53	5.98	4.50	4.67	34.44
1834...	1.57	1.13	1.43	3.13	5.61	5.10	7.58	1.15	3.81	4.64	3.50	2.97	41.62
1835...	3.50	1.20	4.60	4.06	1.50	1.95	2.84	2.25	0.83	3.26	1.72	3.25	30.96
1836...	5.63	3.45	5.00	2.30	2.51	3.25	1.53	0.72	1.03	2.35	5.25	4.85	37.87
1837...	1.40	2.65	3.17	4.65	7.28	2.82	1.38	2.00	0.48	1.29	1.95	2.55	31.62
1838...	2.70	2.32	2.70	2.70	3.88	3.30	0.66	3.55	6.76	4.61	3.65	1.08	37.91
1839...	0.76	1.50	1.50	3.63	3.79	2.31	5.26	5.00	1.83	3.75	2.30	5.12	36.75
1840...	2.80	2.05	3.50	3.45	3.35	2.91	3.38	3.20	2.95	5.17	5.35	3.10	41.21
1841...	6.45	1.50	2.86	7.78	2.18	0.98	5.13	5.12	2.35	3.20	4.45	5.86	47.86
1842...	1.30	4.05	2.07	2.10	3.40	9.65	1.48	3.35	1.40	1.16	3.82	3.93	37.71
1843...	0.60	5.27	5.58	4.34	3.50	2.12	1.83	6.23	2.20	6.45	1.35	3.03	42.50
1844...	4.32	1.95	4.75	0.67	1.95	1.15	4.43	1.11	2.83	5.80	3.30	2.75	35.01
1845...	3.20	2.70	3.53	2.34	2.85	2.32	3.10	5.63	1.63	3.40	9.08	3.48	43.26
1846...	1.82	2.08	2.86	1.75	4.58	1.40	1.44	2.73	2.33	1.85	4.62	3.15	30.61
1847...	2.13	2.71	3.17	1.72	2.02	6.98	2.28	5.50	8.35	1.95	5.72	5.97	48.50
1848...	4.82	3.80	2.40	0.95	5.00	3.80	1.85	3.73	2.45	4.05	3.80	3.83	40.48
1849...	0.80	0.60	5.99	1.62	3.43	1.23	2.00	3.39	3.14	6.55	2.42	3.52	34.69
1850...	5.60	3.38	5.19	4.67	5.00	2.60	2.35	7.65	5.00	2.10	2.10	5.85	51.49
1851...	1.93	3.87	2.00	7.80	3.53	1.90	5.19	3.77	2.47	3.20	5.05	2.62	43.38
1852...	2.70	3.08	3.55	6.65	2.00	1.10	1.63	8.00	1.40	1.30	4.60	3.70	39.76
1853...	4.27	5.75	1.35	5.05	4.95	0.90	6.37	8.38	3.80	4.15	4.40	3.90	53.27
1854...	1.80	4.85	2.85	6.40	3.60	3.70	2.45	0.30	6.10	1.90	9.25	3.35	46.55
1855...	6.45	4.05	0.95	2.50	2.55	1.95	3.55	2.02	0.25	5.33	3.75	6.10	39.45
1856...	5.25	0.80	1.55	2.80	4.10	2.47	4.20	5.75	5.10	1.15	2.05	5.80	41.02
1857...	5.50	2.35	3.35	6.29	4.33	1.90	3.45	4.80	2.27	2.90	2.40	5.20	44.74
1858...	3.33	2.80	2.05	3.63	2.35	5.55	4.90	8.20	3.05	2.80	3.40	3.45	45.51
1859...	5.75	1.85	8.00	2.28	3.40	7.06	1.14	3.69	3.65	2.62	2.27	3.45	45.16
1860...	1.00	3.54	1.80	1.55	1.65	4.02	3.09	5.70	5.38	2.10	3.95	4.66	38.44
1861...	4.87	2.95	4.62	7.75	3.22	4.61	2.21	4.50	2.75	2.17	3.20	1.40	44.25
1862...	6.06	3.15	4.12	1.60	2.60	6.75	3.52	1.47	7.35	4.77	6.85	2.10	50.34

TABLE No. 19.—*Concluded*

PROVIDENCE RAINFALL.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	For the Year.
1863...	4.61	4.04	4.88	5.52	2.33	1.90	9.42	4.59	1.74	2.97	7.51	5.66	55.17
1864...	4.66	1.53	4.74	2.46	3.15	1.22	1.46	4.05	2.36	2.85	3.42	4.95	36.85
1865...	5.29	5.45	5.56	2.98	6.23	1.56	3.91	0.74	0.27	4.60	4.03	4.08	44.70
1866...	2.35	5.64	4.29	2.02	5.29	4.43	2.03	3.54	5.75	2.78	3.97	3.96	46.05
1867...	5.72	6.80	5.32	2.24	3.94	1.56	3.15	8.23	0.62	4.07	2.59	2.80	47.04
1868...	4.56	1.71	4.63	7.02	10.57	4.42	2.09	4.55	5.95	1.23	4 39	2.40	53.52
1869...	3.92	5.19	6.34	2.07	5.20	5.63	0.88	1.58	5.08	5.92	2.19	4.70	48.70
1870...	6.22	3.34	5.47	5.50	2.55	8.22	2.48	1.71	2.11	5.62	2.83	2.97	49.02
1871...	2.35	3.80	5.25	3.81	3.80	5.57	3.63	5.73	1.00	6.68	3.35	2.94	47.91
1872...	2.45	1.56	5.02	2.35	3.64	3.03	5.31	6.12	6.18	5.34	4.95	2.76	48.71
1873...	5.56	4.60	3.67	3.57	4.62	2.74	2.89	7.89	2.17	4.80	5.16	4.99	52.66
1874...	3.62	4.40	2.00	8.54	3.04	3.21	2.58	7.71	2.20	0.92	2.66	2.51	43.39
1875...	3.54	3.76	4.57	5.02	3.44	7.27	3.56	8.85	2.05	4.07	5.12	0.97	52.22
1876...	1.28	4.42	9.75	4.24	3.23	1.40	4.14	1.82	5.73	2.15	6.95	5.25	50.36
1877...	4.55	0.33	7.99	2.40	4.40	4.60	3.60	6.41	0.90	5.81	6.41	1.40	48.80
1878...	3.53	5.70	3.86	6.53	2.41	5.53	2.78	4.68	1.51	5.50	9.96	7.33	59.32
1879...	3.42	4.80	6.36	5.58	1.53	3.74	4.94	6.06	2.92	1.20	2.89	4.13	47.57
1880...	3.26	6.30	5.20	3.92	1.00	1.26	7.31	6.25	2.52	3.69	3.78	3.79	48.28
1881...	6.80	7.30	6.30	1.88	2.72	7.35	4.93	0.59	2.44	2.97	5.60	4.08	52.96
1882...	8.43	5.50	4.13	3.39	4.61	2.80	2.32	1.84	9.43	3.35	2.35	3.69	51.84
1883...	6.68	5.11	2.80	2.38	5.21	1.52	3.83	1.00	3.01	6.30	3.12	4.66	45.71
1884...	5.83	7.29	5.48	4.97	3.85	4.66	3.70	4.86	1.48	3.30	4.28	7.80	57.50
1885...	7.02	4.66	1.67	3.43	4.25	2.50	2.65	4.78	0.80	5.51	3.59	2.71	43 57
1886...	7.10	11.31	3.28	2.87	3.86	1.31	1.99	4.22	2.77	3.53	3.86	5.92	52.02
Totals	216.64	201.72	220.31	207.35	201.16	187.65	178.78	232.76	168.96	199.12	228.47	216.77	2,459.69
Means	3.94	3.67	4.01	3.77	3.66	3.41	3.25	4.23	3.07	3.62	4.15	3.94	44.72

I am indebted to E. B. Weston, C. E., for this table.—D. F.

FALL MEETING.

WEDNESDAY SEPT. 14, 1887.

The fall meeting of this society was a genuine outing, and no business was attempted except the election of four new members.

The party numbering 38 with 13 ladies, left Boston on the morning of the 14th inst., and a few hours later took the steamer Mt. Washington for a delightful sail across the lovely Lake Winnepesaukee—Smile of the Great Spirit,—in the Indian Tongue. President Darling presided at the brief meeting held in the steamer's cabin, and the following gentlemen were elected members of the association :

ACTIVE RESIDENT MEMBERSHIP.

Charles H. Swan, C. E. Boston, Sylvanus D. Horton, Secretary, Pawtucket, Charles E. Pierce, Supt. East Providence.

NON RESIDENT ACTIVE MEMBERSHIP.

Joseph A. Lockwood, Yonkers, N. Y.

Dinner was served on board, and was appreciated, as it deserved to be. A short stay at Center Harbor, and the return sail across the lake, beautiful with afternoon shadows from Rattlesnake island, finished the excursion, and the party rolled into the Boston & Maine station about 8 P. M. well assured that the day had been a pleasant one.

There were present on this excursion.

M. M. Tidd and two ladies, Boston, D. N. Tower and lady, Cohassett, F. L. Fuller and lady, Boston, Wm. Wilcox and lady, Waltham, C. E. Pierce and lady, East Providence, Edwin Darling and lady, Pawtucket, A. F. Noyes and lady, West Newton, William Rotch, Boston, L. A. Taylor Prof. A. R. Leeds, Hoboken, A. S. Glover, West Newton, W. F. Learned Watertown, R. C. P. Coggeshall New Bedford, Charles H. Baldwin Boston, John C. Kelley, New York, J. H. Cunningham, Boston, E. B. LeBarron and Lady, Middleboro, A. F. Polsey, Boston, E. H. Rice and Lady, Boston, E. F. Pierce, Boston, H. F. Jenks and Lady, Pawtucket, H. G. H. Tarr, New York, Jason Giles and Lady, Indian Orchard, H. C. Wood, West Newton.

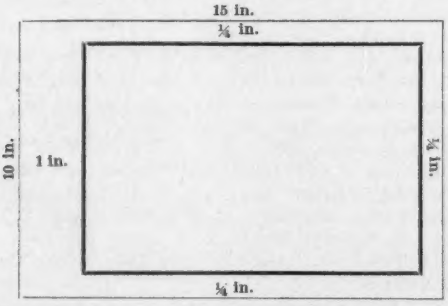
EXCHANGE OF SKETCHES.

The close of the year 1887 finds every water works superintendent occupied in preparing his annual report.

A true record of the operations of the past season must be presented to his superiors, showing actual amount of work, new and old which has been performed, and its cost. This report will likewise contain a concise account of the regular routine work, including any interesting or difficult feature which may have presented itself.

It is a very opportune time while thus engaged, for our worthy members to select some interesting fact for the subject of a "sketch" to be presented at the next annual meeting of the N. E. W. W. Association. There is not one of us but has had some difficulty to overcome,—some special device or arrangement perhaps to improvise, to overcome it—some new construction to build—some old to repair and can tell us how long it has been in service, showing changes from original if any were made. In fact a hundred things have happened during the season that would be of value to the other members, but they have been buried in the hurry of a busy summer. It is to be hoped that during this review of the year's operations everyone will find "meat" with which to serve his brother, seeing to it that the same is complete and ready before another busy season is upon us.

The essential thing is that each one of us should make a pen and ink sketch upon paper of the size and with the margin indicated on this diagram.



Having gone thus far, those who can get the use of a blue print frame, a cyclostyle, or a hektograph have only to reproduce the original according to the method peculiar to each apparatus.

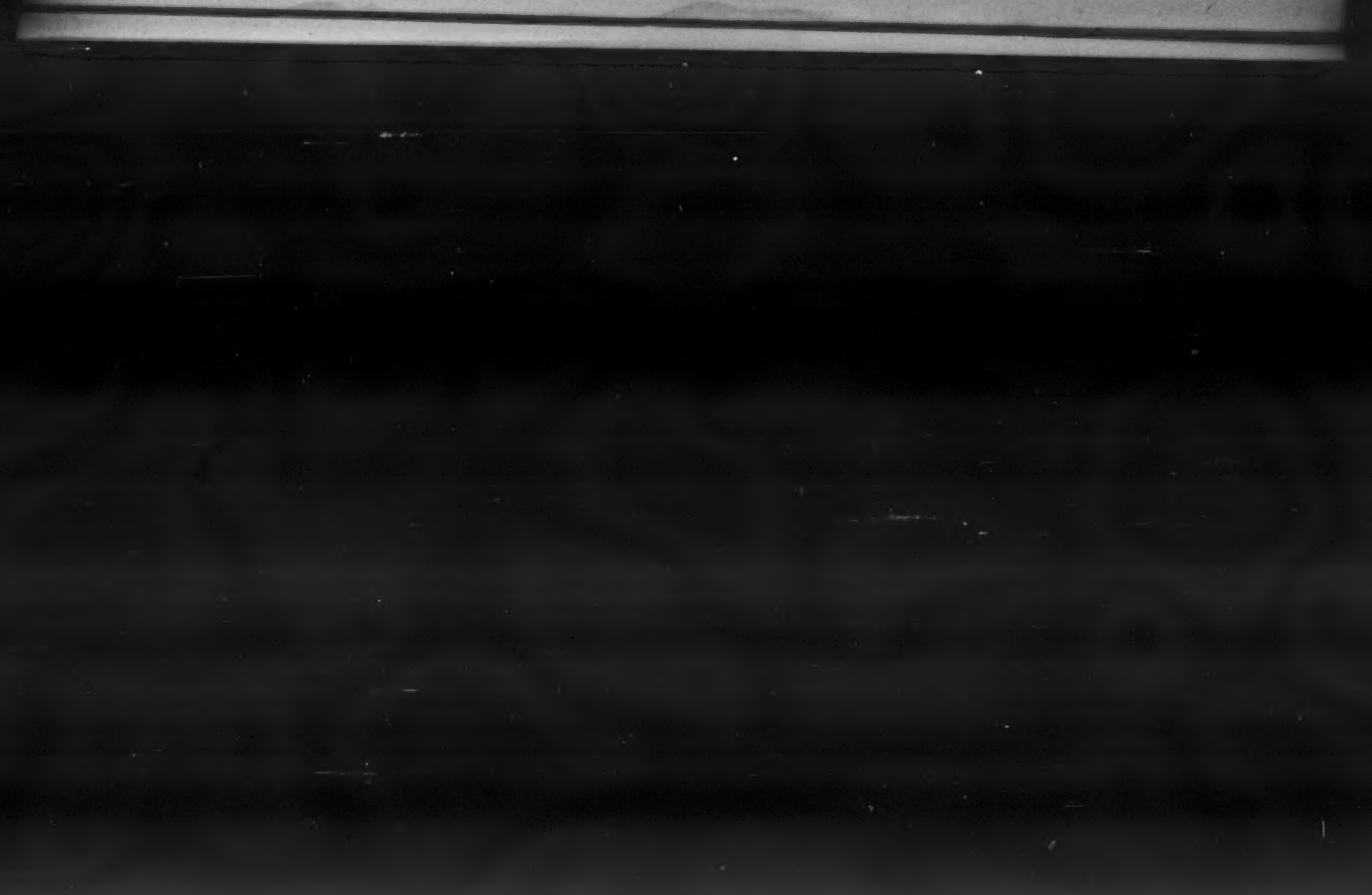
Those who have no means for reproduction are invited to send the sketch to the Secretary, who will make arrangements to have the printing done at the lowest obtainable rates.

OBITUARY.

The death of PHINEAS SPRAGUE on the very day of our fall excursion removes one whose genial presence will be sadley missed at our future gatherings.

Mr. Sprague was born in Malden in January 1823, and first went into business as a dry goods dealer. He was an assessor for Malden for fifteen years, until the town became a city. He was a member of the legistature in 1858: treasurer and collector from 1852 to 1860, succeeding his father in that office: member of the board of selectmen in 1870: and took the United States Census for Malden, Melrose and Everett in 1870. He was the first and only Water Registrar the City of Malden had to the day of his death, and was a member of the Odd Fellows and Masons. One of his official associates said of him "A more just a more honest man than Phineas Sprague never drew the breath of life. He never injured a man in all his life". Higher praise than this no man need ask.

He was one of the original members of this Association, being the fifth man to sign the constitution. He leaves a widow and one son.



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